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VENTILATION AND INDOOR AIR QUALITY

REVISION OF INDOOR ENVIRONMENTAL STANDARD EN 15251

PERFORMANCE OF RESIDENTIAL VENTILATION

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General Executive: Süleyman Bulak

Editor-in-chief: Olli Seppänen
oseppanen@rehva.eu

Associate Editor: Stefano Corgnati, Italy

Editorial assistant: Cynthia Despradel

Guest Editor: Prof. Bjarne Olesen
E-mail: bwo@byg.dtu.dk

ADVERTISEMENTS
Ms Cynthia Despradel
cd@rehva.eu

REHVA OFFICE
Washington Street 40
1050 Brussels, Belgium
Tel: 32-2-5141171, Fax: 32-2-5129062
info@rehva.eu, www.rehva.eu

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Teknik Yayıncılık Tanıtım A.Ş.
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Ventilation and Indoor Air Quality

Prof. Bjarne W. Olesen
Guest editor
International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark
bwo@byg.dtu.dk

Ambient (outdoor) air quality in cities in industrialized countries has improved greatly in recent decades. During this same period, indoor air quality has declined because of energy conservation, decreased ventilation and the introduction of many new materials and sources of indoor pollution. These developments and the fact that people in industrialized countries spend 90% of their lives indoors on average makes the quality of indoor air an important environmental issue with far-reaching implications for human health. Allergic and asthmatic diseases have doubled in industrialized countries during the past two decades. They comprise one of the greatest current problems for public health, with enormous costs for medicine, treatment and absenteeism. In many industrialized countries, half the schoolchildren suffer from these allergic diseases, which are the main reason for absenteeism in schools.

Indoor air quality has declined partly because of comprehensive energy conservation campaigns and partly because high energy prices have motivated people to tighten their dwellings and reduce the rate of ventilation, so that the air change rate in many homes is at a historically low level. Other factors contributing to poor indoor air quality are the many new materials, especially polymers, and the numerous electronic devices that have been introduced indoors in recent decades, especially in children's rooms. The increasing societal need for energy efficiency will often result in very tight buildings. This means that the amount of outside air supplied by infiltration is not enough to provide the required ventilation.

Until now we do not have a clear definition of and clear criteria for indoor air quality. Today an acceptable indoor air quality is mainly defined by specifying the required level of ventilation in air changes per hour or outside air supply rate. This would be equivalent to defining the requirements for thermal comfort by specifying the level of heating or cooling in Watts.

Even if we today have standards and guidelines for estimating the required minimum ventilation rate, they are far from being complete. The goal is of course to be able to calculate the required ventilation rate as straightforwardly as in cooling load calculations. We need to know the requirements for acceptable indoor air quality based on health, comfort and performance and we need to know the emission rates from all the sources. Unfortunately, this is not as easy as in cooling load calculations, where room and outside temperature (°C), energy emission (watts), heat storage, solar radiation (watts) are all evaluated with similar units and all affect the same parameter of the human body (heat balance). For indoor air quality, we have thousand of substances that are emitted from people, furnishing, systems, from outside etc., each of which may affect one or more organs of the body.

We have good knowledge about the required ventilation for the "people" component, while the "building" component is not very well documented. There is an urgent need for better certification and labeling of the materials used in buildings and we must also develop ventilation standards that favour the manufacturers of "good" (low polluting) materials.

There is an increased interest in the development of air cleaning equipment. This may be an acceptable way of reducing the amount of outside air, saving energy and still having an acceptable indoor air quality. However, better test methods for air cleaners are required, because at present the test is usually based on chemical measurements and the resulting effect on odour or perceived air quality is not taken into account. It is also very important to specify which kind of "pollutants" should be used when testing. Some air cleaners may work well on VOC's (emission from materials) but have zero or even a negative effect if the source is people (bioeffluents).

One serious problem is how to ventilate if a building is located in an area with poor outside air quality or if there is a time of the day (e.g. rush hour) when the outside air quality is unacceptable. In some cases it might even be better to reduce ventilation under these circumstances, and the use of air cleaning technologies can be a better solution.

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Revision of EN 15251: Indoor Environmental Criteria

Abstract: EN15251 specifies indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. This standard has now been available for 5 years and will be revised. The paper presents several issues to be discussed in the planned revision. The presented issues are dealing with the thermal environment (when to use adaptive model and criteria for personalized systems), indoor air quality (ventilation effectiveness, air cleaning, adapted/non-adapted occupants, and personalized ventilation), acoustic (introduction of categories), lighting (introduction of categories, daylight factor) and finally occupant behaviour.

Bjarne W. Olesen
Professor
International Centre for Indoor Environment and Energy,
Department of Civil Engineering, Technical University of Denmark
bwo@byg.dtu.dk

Introduction

Energy consumption of buildings depends significantly on the criteria used for the indoor environment (temperature, ventilation and lighting) and building (including systems) design and operation. Indoor environment also affects health, productivity and comfort of the occupants. Recent studies have shown that costs of poor indoor environment for the employer, the building owner and for society, as a whole are often considerable higher than the cost of the energy used in the same building. It has also been shown that good indoor environmental quality can improve overall work and learning performance and reduce absenteeism. In addition uncomfortable occupants are likely to take actions to make themselves comfortable which may have energy implications. An energy declaration without a declaration related to the indoor environment makes no sense. Thus there is a need for specifying indoor environmental criteria for design, energy calculations, performance and operation of buildings.

EN15251 specifies how design criteria can be established and used for dimensioning of systems. The standard how to establish and the main parameters to be used as input for building energy calculation and long term evaluation of the indoor environment. Finally the standard identifies parameters to be used for monitoring and displaying of the indoor environment as recommended in the Energy Performance of Buildings Directive.

The standard is now up for review and there is a wish also to adopt this standard at the ISO level. The revision must be based on experience gathered from application of the standard both in the field and by more theoretical studies.

Thermal Environment

The following issues must be discussed during the revision of the standard.

- Clear differentiation between the adapted and PMV-PPD approach
- Personalized systems
- Local thermal comfort parameters

Adapted versus PMV-PPD approach

The use of the standard has shown it is needed to make it clearer when the adapted concept can be used (residential buildings, passive cooling). When comparing the two concepts in more temperate climates like Copenhagen it can be seen (**Figure 1**) that the adapted approach specifies lower room temperatures in early and late summer. For sedentary occupation the requirements for mechanical condition buildings (based on the PMV-PPD index) is an operative temperature range in winter 20-24°C and summer 23-26°C, which is shown in **Figure 1** with the blue and yellow squares. The adapted approach in 15251 shows a little more variations (running mean outside temperature) than ASHRAE-55 (monthly average outside temperature). The maximum temperature during summer is almost the same for the two approaches. During the summer period (May-October) the adapted approach do however specify room temperatures lower than 26°C and thus a stricter requirement.

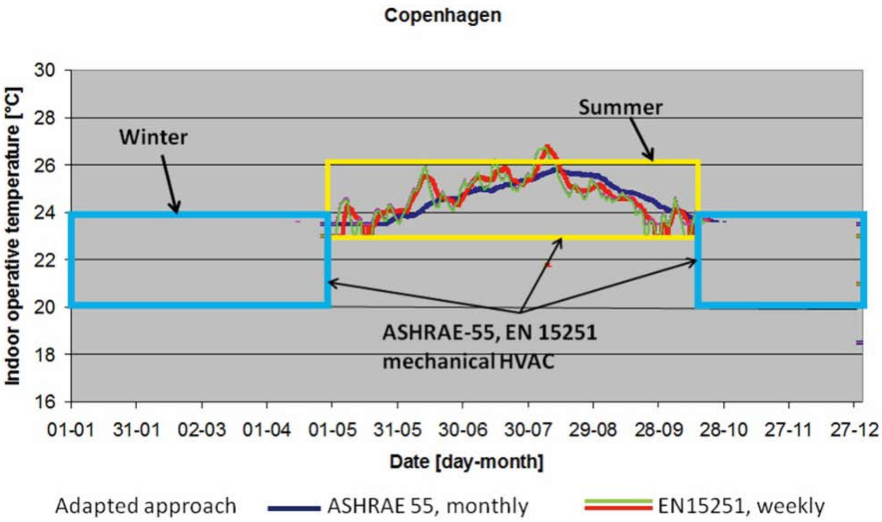

Figure 1. Recommended requirements for the indoor operative temperature based on the adapted approach and PMV-index from ASHRAE-55 and EN15251. ASHRAE adapted approach is based on a monthly average outside temperature, in EN15251 it is based on a weekly weighted outside temperature.

In the present standard the PMV-PPD index is mainly presented by giving recommended temperature intervals for the different categories of thermal environment. More emphasis should be put on how to use the PMV-PPD index in a more flexible way i.e. taking into account the cooling effect of increased air velocity.

Personalized systems

During the last decade several systems for providing a high quality personal indoor environment have been studied and tested. Also several products/systems are now available on the market. The existing standards with criteria for the indoor environment (thermal, air quality, noise , light) are all based on criteria for the whole occupied zone (ISO EN 7730, EN15251, ASHRAE-55, ASHRAE-62.1). Can these criteria be directly applied also to a personal system, where the occupants try to meet their own preferences? If the occupants have a personalized system is it then possible to relax on the requirements to the general environment? These are some of the issues that will be discussed in the revision of the standard. Based on the many studies found in the literature on personalized systems for control of thermal comfort, air quality, lighting and noise a set of criteria for the personalized environment should be established. At the same time recommended changes in the existing criteria for the general environment should be made.

Personalized indoor environmental systems can provide the occupant with an individual control of thermal comfort, perceived air quality, illumination and masking of noise. In general for illumination and noise you can use the same criteria for a personalized environment as for a general environment. Most personalized systems blow air towards the occupant (**Figure 1**)

This set-up will mainly influence the perceived air quality and increase cooling due to an increased air velocity and may be lower air temperature of the supply air. But also the classification of the Indoor environment will be influenced due to better CO_2-level within the Personalized Environmental zone. As shown in **Figure 2** a personalized system may divide the space in two zones, one close to the occupant and a general zone. The question is if it should be allowed to relax the indoor environmental criteria for the general zone if a personalized system is available. The increased ventilation effectiveness should allow a decrease of the supply ventilation rate. This can be taken into account by correcting the required ventilation rates in the standard tables (based

Figure 2. Typical set-up of personalized ventilation system.

on complete mixing) with the ventilation effectiveness (see below).

Local thermal comfort parameters

In the present standard local thermal comfort parameters like asymmetric radiant temperature, draught, vertical air temperature differences and surface temperatures are not included as these parameters may not have a direct influence on the energy consumption in buildings. They do however have an influence on the design and dimensioning of buildings and HVAC systems and then also on the energy consumption.

Indoor Air Quality and Ventilation

The standards approach to indoor air quality is to specify a recommended level of ventilation (outside air), depending on number of occupants in the space and a contribution depending on the floor area of the space. There is however a need for some clarification and new concepts regarding these issues:

- Ventilation for Non-adapted or adapted occupants
- Use of increased CO_2 level as IAQ indicator
- Air cleaning as substitute for outside air
- Ventilation effectiveness
- Personalized ventilation

Ventilation for non-adapted or adapted occupants.

For the prescriptive method, a minimum ventilation rate per person and a minimum ventilation rate per square metre floor area are required. The two ventilation rates are then added. The person-related ventilation rate should take care of pollution emitted from the person (odour and other bio effluents) and the ventilation rate based on the person's activity and the floor area should cover emissions from the building, furnishing, HVAC system, etc.

The design outdoor airflow required in the breathing zone of the occupied space or spaces in a zone, i.e., the breathing zone outdoor airflow (V_{bz}), is determined in accordance with the equation:

$$V_{bz} = R_p P_z + R_a A_z \quad (1)$$

Where:

A_z = Zone floor area: the net occupied floor area of the zone m²,

P_z = Zone population: the greatest number of people expected to occupy the zone during typical usage.

R_p = Outdoor airflow rate required per person: these values are based on un-adapted occupants in EN15251 and adapted in ASHRAE-62.1.

R_a = Outdoor airflow rate required per unit area.

In the standard different methods for calculating the recommended ventilation rate are included. As a minimum it must be ventilated to dilute the bio effluents from the occupants (people component, R_p, see **Table 1**).

Table 1. Smoking free spaces in commercial buildings according to ASHRAE 62.1 and EN15251.

Type of building/ space	Occupancy person/m²	Category EN	Minimum ventilation rate, i.e. for occupants only l/s person		Additional ventilation for building (add only one) l/s·m²				Total l/s·m²	
			ASHRAE R_p	EN	EN Very low-pollut.	EN Low-pollut.	EN Not low-pollut.	ASHRAE R_a	EN Low Pol.	ASHRAE
Single office	0,1	I	2,5	10	10	1,0	2,0	0,3	2	0,55
		II		7	7	0,7	1,4		1,4	
		III		4	4	0,4	0,8		0,8	
Land-scaped office	0,07	I	2,5	10	10	1,0	2,0	0,3	1,7	0,48
		II		7	7	0,7	1,4		1,2	
		III		4	4	0,4	0,8		0,7	
Conference room	0,5	I	2,5	10	10	1,0	2,0	0,3	6	1,55
		II		7	7	0,7	1,4		4,2	
		III		4	4	0,4	0,8		2,4	
Classroom	0,5	I	3,8	10	10	1,0	2,0	0,3	6	2,2
		II		7	7	0,7	1,4		4,2	
		III		4	4	0,4	0,8		2,4	

These rates are in EN15251 specified for three categories of indoor air quality, based on the prediction that a certain percentage of visitors will find the air quality unacceptable. The design levels are thus adequate for people who walk into a space. It is debatable if this should always be the case. People adapt very quickly to the odour (bio effluents) in a space while there is less adaption to emissions from building materials and tobacco smoke (odour and irritants, [2]). To provide an acceptable perceived air quality for occupants (who have adapted to the air quality for at least 15 min.) it is estimated that one third of the ventilation rate is sufficient i.e. for category II 2,5 instead of 7 l/s per person. The ASHRAE Standard 62.1 for ventilation and indoor air quality defines ventilation levels for adapted persons (occupants). In addition, the minimum recommended ventilation is increased with a building-related ventilation rate, in order to take into account the emissions from the building and its systems (see **Table 1**). There is, however no general agreement on whether the contribution from the building should be added in full. Several studies indicate this is the best approximation, but it may not be valid for all types of pollutants. Here it is the contribution to the odour and irritation (perceived air quality) which must be taken into account. So it can be argued that they all influence one organ (the nose) and so should be added. When the health risk is considered a simple addition can be made for the same chemical component; but not for different chemical components if they influence different body organs.

Table 1 shows the required ventilation rates from standard EN15251 compared to ASHRAE 62.1.

There are quite big differences between the European recommendations and those listed by ASHRAE. One major reason is that ASHRAE requirements are minimum code requirements, where the basis for design is adapted people, while the European recommendations are for un-adapted people (visitors). Who should we ventilate for? For people just entering the room (unadapted) or for people already occupying a room (adapted)? Here the philosophy adopted by ASHRAE 62.1 and EN15251 differs. But should it really be one or the other? In a conference room, auditorium or lecture room most people enter at the same time. It then takes some time before the odour level has reached an unacceptable level and meanwhile people adapt. In this case it may be appropriate to require a ventilation rate based on adapted persons. There may be other spaces where you would design for un-adapted people, e.g. in a first class restaurant, offices, and department stores. It seems logical that more differentiated criteria could be used.

Use of increased CO_2 level as IAQ indicator

In the standard are also listed a CO_2 criteria for three categories; but the values are not consistent with the required ventilation rates listed in **Table 1**. Knowing the CO_2 production from the occupants it is possible to calculate the increased CO_2 level compared to outside, which corresponds to the total ventilation rates (see **Table 2**).

Air cleaning as a substitute for outside air

Air cleaning is not taken into account at all in EN15251, while ASHRAE 62.1 by using the analytical procedure allows some credits for air cleaning. There is an increased interest in the development of air cleaning equipment. This may be an acceptable way of reducing the amount of outside air, saving energy and still have an acceptable indoor air quality. However, better test methods for air cleaners are required, because at present the test is usu-

Table 2. Equivalent increase in CO_2 levels indoor for the total ventilation rates specified in Table 1.

Type of room or building	Category	Very low-polluting ΔCO_2 [ppm]	Low-polluting ΔCO_2 [ppm]	Not low-polluting ΔCO_2 [ppm]
Single office	I	375	280	190
	II	560	400	265
	III	930	695	465
Landscape office	I	310	220	140
	II	465	310	195
	III	745	530	340
Conference room	I	510	465	400
	II	735	665	570
	III	1265	1160	995
Class room	I	510	465	400
	II	735	665	570
	III	1265	1160	995

ally based on chemical measurements and the resulting effect on odour or perceived air quality is not taken into account. It is also very important to specify which kind of "pollutants" should be used when testing. Some air cleaners may work well on VOC's (emission from materials) but have zero or even a negative effect if the source is people (bio effluents). There is an increasing development of methods and products for gas phase air cleaning including both adsorptions filters and air cleaners using a chemical reaction to remove certain gasses (PCO-Photo Catalytic Oxidisation). CEN-ISO and ASHRAE are developing standard test methods, which will measure the air cleaning efficiency or the equivalent amount of outside air called Clean Air Delivery Rate, CADR

If we work with classes one option could be that even with air cleaning you must have a level of ventilation corresponding to the lowest class. With air cleaning you can then reach a higher class without increasing the amount of outside air. It is therefore recommended that the standard specifying indoor air quality as a certain ventilation rate open up for the possibility to partly use air cleaning as a substitute for outside air.

One serious problem is how to ventilate if a building is located in an area with poor outside air quality or if there is a time of the day (e.g. rush hour) when the outside air quality is unacceptable. In some cases it might even be better to reduce ventilation under these circumstances. For testing gas phase air cleaning a known gas is used to simulate pollution (i.e. toluene to simulate VOC's). The concentration is measured before and after the air cleaner. The air cleaning efficiency is calculated as:

$$\varepsilon_{clean} = (C_U - C_D)/C_U \cdot 100 \qquad \%$$

where

ε_{clean} = air cleaning efficiency
C_U = gas concentration before air cleaner
C_D = gas concentration after air cleaner

The criteria for the ventilation rates shown in **Table 1** are mainly based on perceived air quality PAQ, which is measured by a human test panel. It is therefore also important to be able to test the air cleaning efficiency in relation to the perceived air quality. The air cleaning efficiency can be expressed as:

$$\varepsilon_{PAQ} = Q_o/Q_{AP} \cdot (PAQ/PAQ_{AP} - 1) \cdot 100 \qquad \%$$

where

ε_{PAQ} = air cleaning efficiency for perceived air quality
Q_o = ventilations rate in l/s
Q_{AP} = air flow through the air cleaner l/s
PAQ = perceived air quality without the air cleaner, decipol
PAQ_{AP} = perceived air quality with the air cleaner, decipol

The Clean Air Delivery Rate is calculated as:

$$CADR = \varepsilon_{PAQ} \cdot Q_{AP} \cdot (3{,}6/V) \qquad h^{-1}$$

where

Q_{AP} = air flow through the air cleaner l/s
V = volume of the room m^3.

If the air cleaner has been tested based on chemical measurements it should then be allowed to reduce the pollution contribution due to the building in **Table 1** with a factor based on the measured air cleaning efficiency:

$$q_{b,clean} = \varepsilon_{clean} \cdot q_b \quad \text{l/s per m}^2$$

If the efficiency is 50% the contribution from the building in **Table 1** is then reduced to half, which corresponds to a change in the building category from low-polluting to very low polluting when using **Table 1**.

Ventilation effectiveness

The ventilation rates specified in the standards (**Table 1**) are the required rates at breathing level in the occupied zone. The required ventilation rate at the room supply diffusers are calculated as:

Total ventilation rate

$$V = V_{bz} / \varepsilon_v \qquad (2)$$

where:
V_{bz} = breathing zone ventilation

$$\varepsilon_v = \frac{C_e - C_s}{C_i - C_s} \qquad (3)$$

where:

ε_v = Ventilation effectiveness
C_e = Pollutant concentration in extract air
C_s = Pollutant concentration in supply air
C_i = Pollutant concentration at breathing level

The ventilation effectiveness depends on the air distribution efficiency and the type and position of the pollution source(s), so this value is not only a system characteristic. In most cases it is assumed that the pollutant emission is uniform, so the ventilation effectiveness is the same as the air distribution effectiveness. For a fully-mixed ventilation system the value is 1 and the ventilation rates in **Table 1** can be used for the design of the supply grills. The ventilation effectiveness or air distribution efficiency is a function of the position and type of supply and return grills, and depends on the difference between supply and room temperature and on the total amount of airflow through the supply grill. The air distribution effectiveness can be calculated numerically or measured experimentally. Typical examples of ventilation effectiveness/air distribution effectiveness are shown in **Figure 3**.

The rates given in the Tables of standards are based on full mixing and in practice the ventilation effectiveness is very seldom taken into account. One complication is that some systems may have a different ventilation effectiveness summer and winter. If the supply temperature is lower than room temperature the ventilation effectiveness is normally 1 or higher, but if the ventilation system is used for heating in winter the ventilation effectiveness could be as low as 0.5, and the ventilation rates should really be doubled. More information and a greater emphasis on this factor are required.

To use ventilation effectiveness can be one way of taking into account personalized ventilation; but we need also to look at issues like acceptance of higher air velocities and less strict requirements to the general environment if the person is equipped with a personal system.

The air distribution effectiveness takes into account the air distribution in a space, but does not take into account how effectively the outside air is transported through the ducts to the space. If the system has any air leakage, the amount of ventilation air must be increased. This is not dealt with in EN15251, but is mentioned in ASHRAE 62.1.

Illumination

The criteria in EN15251 are only specified at one level of luminance. The following additional criteria for daylight factor (**Table 3**) and seasonal affective disorder (SAD, **Table 4**) should be discussed for inclusion in the standard.

Table 3. Recommended criteria for the daylight factor.

	I	II	III
Daylight factor	> 5% on average	> 3% on average	> 2% on average

Table 4. Recommended criteria for SAD (Seasonal Affective Disorder).

	I	II	III
Direct sunlight availability, percentage of probable sunlight hours	> 10%	> 7,5%	> 5%

For rooms that are used during the day (work places, living rooms, dining rooms, kitchens, or child's play rooms) the minimum daylight factor is:

Illumination in Residential buildings

To reduce the prevalence of SAD (Seasonal Affective Disorder; "winter depression"), higher light levels are particularly important during winter. For minimum one of the main habitable rooms in residential buildings direct sunlight should be available from fall to spring equinox.

Mixing ventilation		Mixing ventilation		Displacement ventilation		Personalized ventilation	
T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T room °C	Vent. effect. -
< 0	0,9 - 1,0	< -5	0,9	<0	1,2 - 1,4	-6	1,2 - 2,2
0 - 2	0,9	-5 - 0	0,9 - 1,0	0-2	0,7 - 0,9	-3	1,3 - 2,3
2 - 5	0,8	> 0	1	>2	0,2 - 0,7	0	1,6 - 3,5
> 5	0,4 - 0,7						

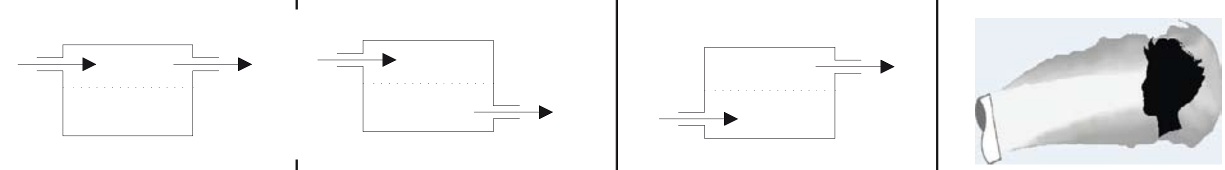

Figure 3. Typical examples of ventilation/air distribution effectiveness. (CEN TR 1752)

Acoustic

The section on acoustic needs to be revised. Again it would be recommendable if experts could suggest different categories of requirements.

Occupant behaviour

The occupant behaviour will have a significant influence on the energy consumption in buildings. In dynamic computer simulations of indoor environment and energy consumption in buildings certain occupant behaviour (temperature set-point, time of occupancy, solar shading etc.) significantly influences the results. Therefore there is a need to specify some "standard" patterns of occupant behaviour.

Conclusions

EN15251 is the first European standard that includes criteria for the four indoor environmental factors: Thermal comfort, air quality, lighting, and acoustic. This standard has been widely used in practice and several scientific papers have been published dealing with issues related to the standard. The present paper has highlighted some of the issues that must be discussed in the future revision of the standard.

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Evaluation methods for indoor environmental quality assessment according to EN15251

Summary: In existing and future buildings there will be an increasing focus on energy uses and indoor environmental quality. Even if buildings are using several different kinds of energy sources, the yearly energy performance is expressed in one format either as primary energy or CO_2 emission. As a consequence, in order to compare energy performance with the corresponding indoor environmental performance, there is a need to express also the indoor environmental performance on a yearly basis, referring both to each separate environmental factor (thermal comfort, air quality, light and noise) and to a combination of these factors. If the indoor environmental criteria in existing standards have to be met 100% of the occupancy time, the amount of heating, cooling and/or ventilation capacity of any HVAC installation would be prohibitive in terms of energy consumptions. Economic and/or environmental considerations lead to a more pragmatic position of allowing the indoor environmental conditions to exceed the recommended ranges for a limited period of time: this can be verified both by computer simulations (design stage) and by the field monitoring (post-occupancy phase).

The present paper will present some concepts to carry out a whole year performance evaluation of the indoor environment, inspired by ISO EN 7730 (thermal environment) or EN15251 (thermal, indoor air quality, light and noise). Besides, some new suggested concepts about indoor environmental quality are tested. Based on data from indoor environmental measurements in an existing building, methods for long term evaluations will be presented and discussed. The results show that the different concepts to a great extend will bring the same relative results. The results also show that today we still do not have enough knowledge to be able to combine the indoor environmental parameters into one synthetic indicator.

The full length version of this article with the references is available at the journal website, http://www.rehva.eu/en/rehva-european-hvac-journal.

Daniela Raimondo
ICIEE, Department of Civil Engineering, Technical University of Denmark, Denmark & TEBE Research Group, Department of Energy, Politecnico di Torino, Italy
daniela.raimondo@polito.it

Stefano P. Corgnati
TEBE Research Group, Department of Energy, Politecnico di Torino, Italy

Bjarne W. Olesen
Professor
ICIEE, Department of Civil Engineering, Technical University of Denmark, Denmark

Introduction

The environmental factors that define the indoor environmental quality (IEQ) are: thermal comfort, indoor air quality, acoustic comfort and visual comfort. This makes it almost impossible to describe the indoor environment in a building on a yearly basis with only one indicator. This is much easier with energy, where the different energy carriers (electricity, fuel, etc.) can be converted to primary energy or CO_2 emission. For the individual indoor environmental factors, there is even not any standardized method for the estimation of a yearly performance descriptor.

Criteria for acceptable thermal conditions are specified as requirements for global thermal comfort (PMV-Predicted Mean Vote, PPD- Predicted Percentage of

Dissatisfied, or operative temperature, air velocity and relative humidity) and local thermal discomfort (draught, vertical air temperature differences, radiant temperature asymmetry, surface temperature of the floor). Such requirements can be found in existing standards and guidelines like EN ISO 7730 (2007) [1], CR 1752 (1998) [2], EN15251 (2007) [3] and ASHRAE 55 (2007) [4]. Moreover for free running or natural ventilated office buildings, the criteria for an acceptable operative temperature are given as a function of the mean outdoor temperature [3] [4].

Different categories of criteria, according to [1] and [3], may be used for IEQ assessment depending on type of building, type of occupants, type of climate and national differences (**Table 1**). Some of the standards specify different categories of indoor environment which could be selected as a reference for the space to be conditioned. These different categories may also be used to give an overall, yearly evaluation of the indoor environment by estimating (through measurements or dynamic building simulations) the percentage of time in each category of the analyzed room or building [5].EN 15251, for example, specifies how criteria about IEQ can be established and used at the design stage; moreover it defines the main parameters to be used as input for building energy calculation and long-term evaluation of the indoor environment [6].

But, if thermal comfort criteria have to be met 100% of the time of occupancy, including extreme weather conditions, the heating and/or cooling capacity of any HVAC installation would be prohibitive. Economic and/or environmental considerations lead to a more pragmatic position of allowing the thermal conditions to exceed the recommended ranges for a limited period time. There is a need to quantify through some suitable index long term comfort conditions to compare alternative design solutions and long term measurements during the post-occupancy phase in existing buildings.

The use of categories during the design stage to evaluate different design options can be done by yearly building energy simulations. In these calculations, the categories may be clearly adopted and performance indicators can be expressed as percentage of time where the indoor environment falls into the different categories. The use of categories to express the quality of the indoor environment during building operation can be based on measurements of the physical parameters. The present paper deals with thermal environment and indoor air quality assessment. Based on data from measurements in an existing office building, different methods for long and short term indoor climate investigations are presented and discussed.

Method

The case study is an office building located in Denmark (Lat: 55.5°, Lon: 9.75°). The building has a complex shape (see **Figure 1**). The total volume is mainly occupied by bank offices, but also a bookshop, a café and a real estate agent office is located at the ground floor level, around a central plaza. The working areas (basically open space offices) are mainly located on three open terraces, called "plateaus", internally connected by broad staircases. On each floor also single

Table 1. Example criteria for PMV-PPD, operative temperature, relative humidity and ventilation (CO_2 concentration) for typical spaces with sedentary activity. [3]

Category	Thermal Comfort indexes		Operative Temperature range		Relative Humidity	Ventilation
	PPD	PMV	Winter 1.0clo/1.2met	Summer 0.5clo/1.2 met		CO_2 Above outdoor
	[%]	[/]	[°C]	[°C]	[%]	[ppm]
I	< 6	-0.2< PMV <+0.2	21.0 - 23.0	23.5 - 25.5	30 - 50	> 350
II	< 10	-0.5< PMV <+0.5	20.0 - 24.0	23.0 - 26.0	25 - 60	350 - 500
III	< 15	-0.7< PMV <+0.7	19.0 - 25.0	22.0 - 27.0	20 - 70	500 - 800
IV	> 15	PMV > ±0.7	< 19.0 - 25.0<	< 22.0 - 27.0<	< 20 - 70<	> 800

Note: In standards like EN ISO 7730, EN15251 and EN 13779 (2007) [7] categories or classes are also used; but they may be named differently (A, B, C or 1, 2, 3 etc.).

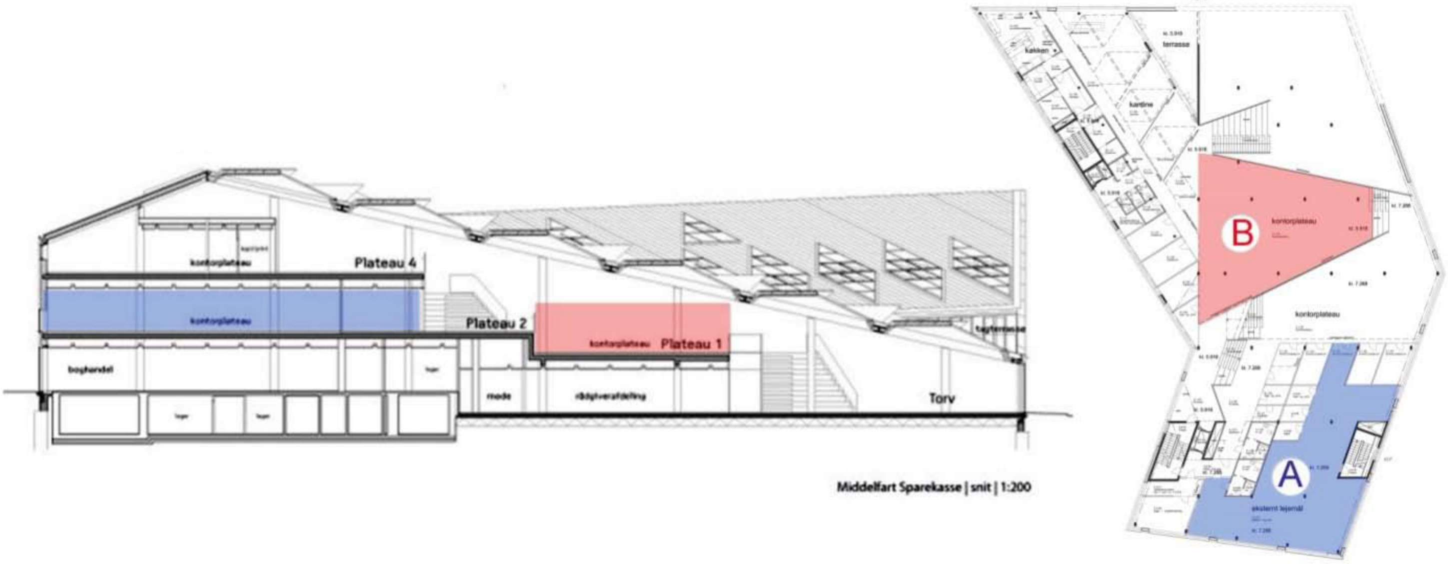

Figure 1. Case study building (vertical and horizontal sections). In evidence the two analyzed rooms located at the first floor (ROOM A and ROOM B).

offices, meeting rooms and other rooms for dedicated services are placed. The building envelope is made mainly by structural glass (U = 1.1 W/m^{2}K), with the transmission coefficient (visible light/solar energy) equal to [0.64/0.35]. The office is normally occupied from 8:00 to 18:00, from Monday to Friday.

The indoor environmental control of the building is divided into two main strategies:

- Type 1: Convectors and balanced mechanical ventilation for heating and ventilation control during the winter period, TABS (Thermo active building system) and HVAC system for cooling and ventilation control during summer. This kind of system is mainly applied in single offices and meeting rooms.
- Type 2: Embedded water based radiant system, and convectors for thermal control. Natural ventilation by controlled window openings to provide acceptable indoor air quality. This kind of strategy is applied in all the large spaces, like in the offices situated on the terraces (plateaus), in the canteen and in the central square at the ground floor.

The monitoring campaign started in July 2010. In this paper, the data collected during winter 2010/2011 and summer 2011 are presented. During that period, measurements of air temperature, operative temperature, relative humidity and CO_2 concentration were collected every 10 minutes in 12 different rooms. Meanwhile, an external weather station collected data of the outdoor air temperature, relative humidity, wind velocity/directions and solar irradiance.

In this paper the investigation of IEQ focuses on two spaces. The first (ROOM A) is an open space office located at the first floor and characterized by control strategy Type 1. The second space (ROOM B) is another open space also located on the first floor, but characterized by control strategy Type 2 (**Figure1**).

Results

The aim of this investigation is to show and compare different method for describing thermal comfort and indoor air quality. In this paper long and short term evaluation applied to the two analyzed office rooms are addressed and discussed.

Standard EN 15251 [3], in annex F ("Long term evaluation of the general thermal comfort conditions"), suggests three different methods (A,B,C) to evaluate and represent the comfort conditions over time (season, year), based on data from measurements in real buildings or obtained by dynamic computer simulations.

One method is based on the calculated number (or %) of hours in occupied period when the PMV or the Operative Temperature are outside a specified range.

Application of this method is shown in **Figure 2**. Here the thermal performance of the two analyzed rooms, in terms of percentage of time according to the four categories of operative temperature and PMV suggested by the standard (**Table 1**), was evaluated both for winter *(a)* and summer *(b)* periods.

Other physical parameters, monitored or deriving by dynamical simulations, can be represented with the same approach. **Figure 2** also shows the percentage of time when the CO_2 concentration and the Relative Humidity exceed the respective ranges indicated in **Table 1**.

Operative temperature and PMV evaluations, show some differences in the results: the operative temperature evaluation gives slightly better results compare to the PMV evaluation. While the first considers just the operative temperature, the PMV calculation depends by

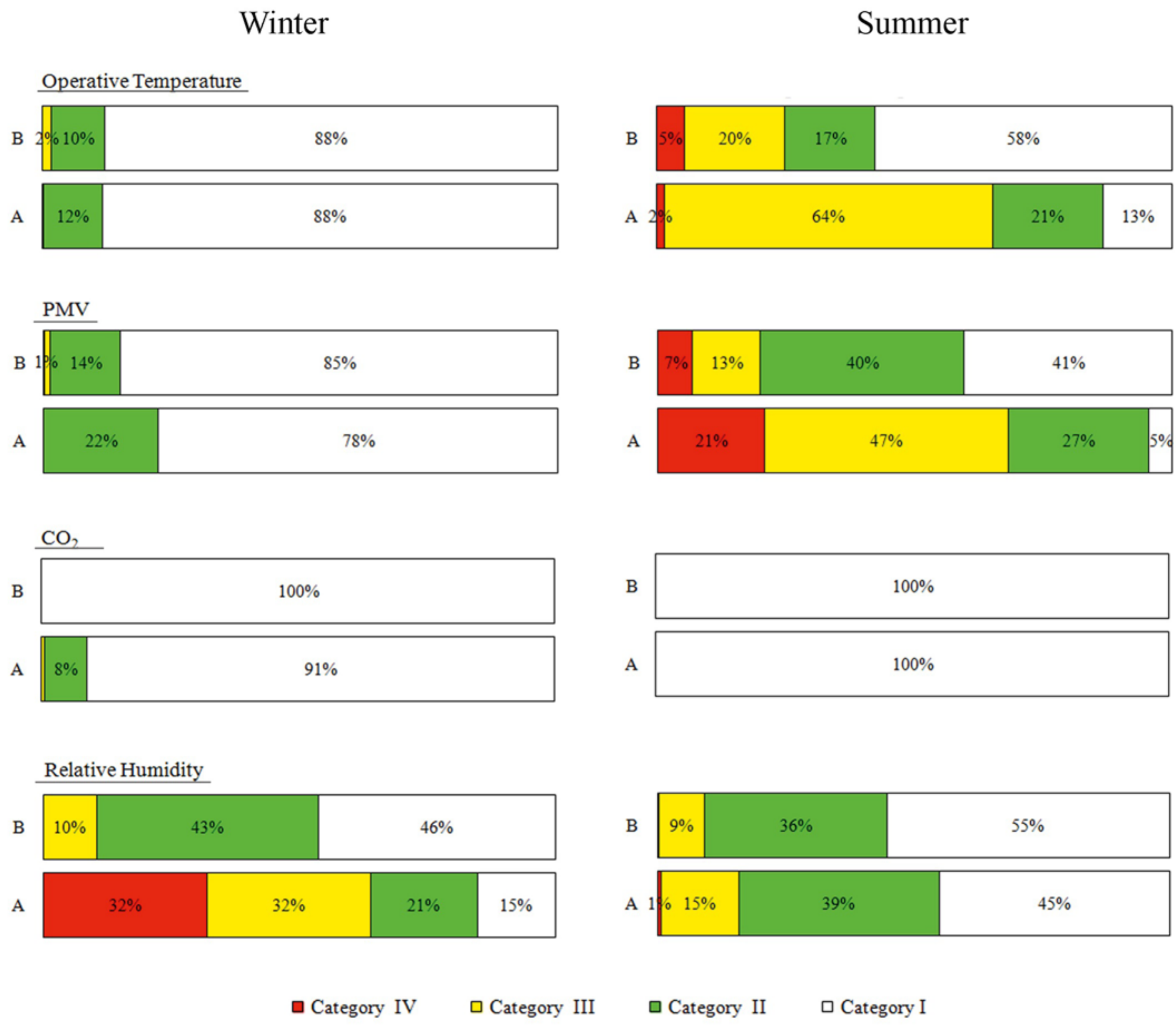

Figure 2. Indoor Operative temperature, PMV, Air quality (CO_2 concentration) and Relative humidity measurements, expressed as percentage of time in four categories, for winter and summer periods.

physical parameters (air temperature, relative humidity, air velocity, mean radiant temperature) and subjective parameters (thermal resistance of the clothes and metabolic rate). In this case study the physical parameters, except to air velocity, were monitored in continuous. Trough spot measurements performed in different periods of the year, it was however possible to establish that the air velocity was averagely around 0.10 [m/s]. For the PMV calculation the air velocity value was then kept constant as 0.10 [m/s]. Regarding the subjective parameters, the metabolic rate used in the analysis was the one indicated by standard ASHRAE 55/2004 for "Office activity-Filing, seated", 1.2 [met]. Also the clothing insulation value was kept constant: 0.5 [clo] in summer period and 1 [clo] in winter period. Due to these assumptions, the PMV calculation does not represent the real PMV of a specific occupant in the room during the monitored time, but it represents the average evaluation of the thermal environment according to the comfort standards for office buildings.

From **Figure 2** it is possible to note that, during the heating period, both the two control strategies, Type 1 and 2 (Room A and B) were able to provide a very good thermal quality in the analyzed rooms. Only a little percentage of time (less than 2%) was in Category III, while for the 88% of time operative temperature felled in Category I. The situation was different in summer period. As shown in the figure during the warm season the thermal quality in both the rooms presents a large percentage of time when the temperature felled in Category III and also a little in Category IV.

This method is a fine way to present the yearly results, but it is not possible to see if the problem is a too warm or too cold environment.. If we analyze Category IV, splitting it in two parts, Category IV$^{(-)}$ when T<22°C and Category VI$^{(+)}$ when T>27°C in summer, it is possible to see that the percentage of time when the temperatures in room B exceed the upper range is negligible. This fact is better shown in the operative temperature profiles of **Figure 3**. According to this analysis the performance in summer is not acceptable because temperatures are too low for a big percentage of time for both cases, A and B. With an optimized control setting under cooling can be avoided and energy saved

Figure 3also show the bigger fluctuation of operative temperature of Room B respect to Room A during the working day. The mechanical ventilation in

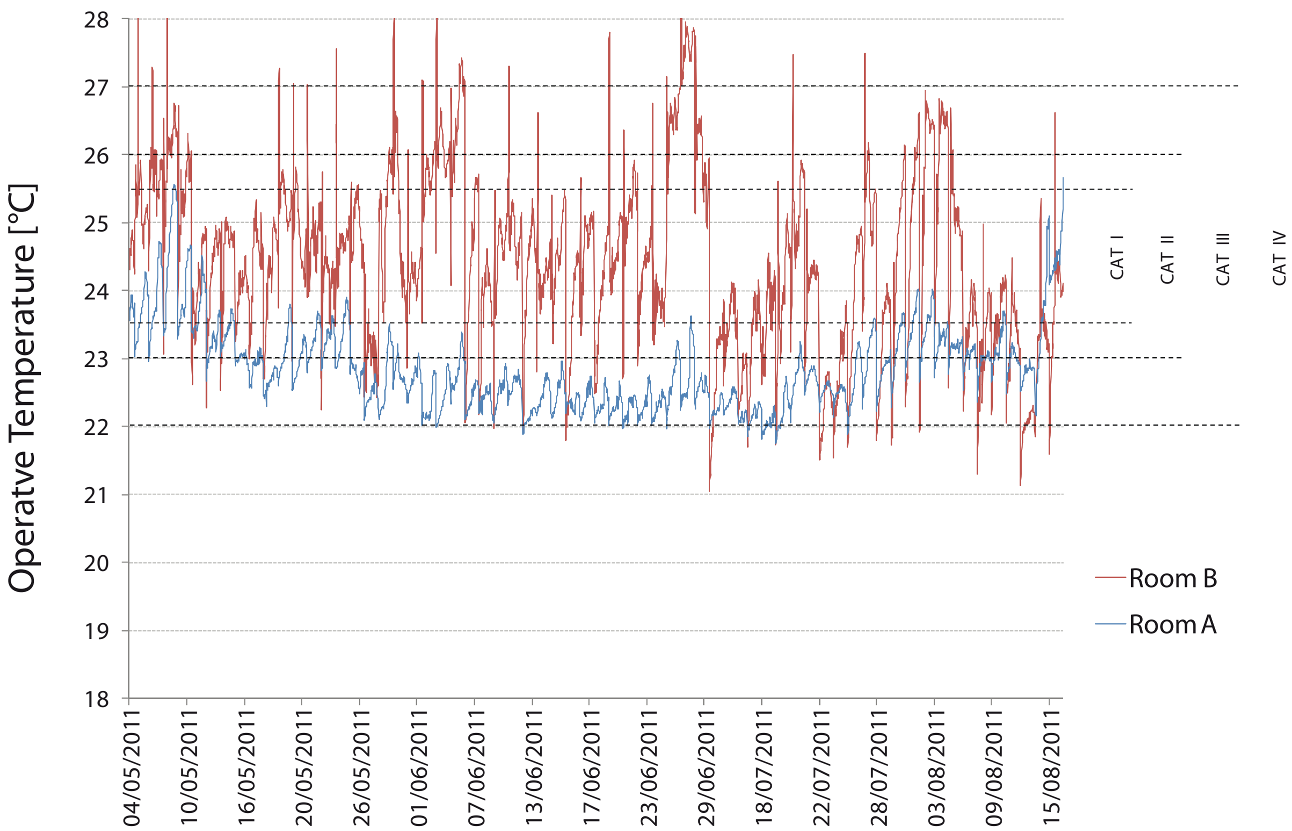

Figure 3. Operative temperature profiles during the occupied hours for Rooms A and B in summer period.

room A contributes to reach the temperature of 23°C with very small fluctuations (< 2-3 K). .While in the natural ventilated Room B, the variations of the operative temperature is larger (> 9 K). The control of the natural ventilation was based on controlled window openings according to indoor temperature and CO_2 concentration.. Looking at this graph, and at the values of **Table 1**, it can be observed that most of the time the outside temperature was lower than the indoor temperature, so natural ventilation could be a useful and economic way to remove and control the heating loads during summer; but to avoid under cooling and the large variations in operative temperature the control of the window openings must be improved.

From **Figure 2** it is also possible to see that for both the rooms, and for both seasons, the CO_2 concentration was very good: the percentage of time when the air quality was in Category I was always greater than 91% in winter period and equal to 100% in summer.

The same figure also shows the relative humidity evaluation: in that case emerges that for both seasons, the best results are in Room B but, as already highlighted before, from this representation is not possible to see that the values falling from Category II to Category IV are lower/higher (winter/summer) than the lower/upper limit of Category I.

Discussions and conclusions

The main idea behind the categories for IEQ assessment is to use them from the design up to the post-occupancy phase for buildings and HVAC systems analysis, in order to provide evaluations about the indoor environment over a longer period like a year. The intention is not to force the operation of a building within one class the whole year, but to critically analyse the possible change of classes over the year. In fact, even if a building is designed for a lower category, it will still be possible to operate the building the majority of the year in a higher category. For building with HVAC systems the categories are based on different levels of the PMV-PPD index and/or operative temperature. If the long term evaluation also will be used to analyse a problem and find solutions it is important to evaluate the deviations outside the categories on the warm and cold side separately. In practice, very often, operative temperature is the reference parameter used in field investigations. It is, however, questionable if fixed temperature ranges should be used for a long term evaluation. In fact, people often adapt their clothing according to the outside climate: this is true for both mechanical and naturally ventilated buildings. This aspect needs to be deeper studied in future researches, in order to take this into account for category range definition.

In this paper the use of categories for the thermal environment and indoor air quality assessment in an office building is performed. Two different environment (naturally ventilated and mechanically ventilated), part of the same office building, are compared. Results and elaboration about long term monitoring in the selected rooms are shown.

Different methods of classification for the long term evaluation suggested by the standards are analysed, and critical aspects are highlighted. A variation of application of one of the method suggested by the standard EN ISO 15251 is presented. 3E

Nordic approaches to improve and validate indoor air systems

Even more focus must be put on well functioning and low energy consumption of Indoor Climate installations, if we are to meet the existing and coming demands for ensuring both control of healthy indoor climates and low energy consumption.

Ventilation Technology for such demands to Indoor air quality is already on the market.

Christen Galsgaard
Sec. General
Dansk Ventilation
info@danskventilation.dk

Installations of indoor air systems – or indoor air installations – have severe cost impact in buildings, and have in most cases been thoroughly designed before any installation works are initiated at the building site.

Everything should be easy to accomplish: Buy the specified components and units, ensure that everything is CE marked as demanded, put the stuff together according to the design engineer's specification. Then, plug in, push the green button and enjoy an excellent indoor air climate. PERFECT.

WHY is this logic not the normal outcome?

Those who are involved in building processes have the knowledge of constraints and bottlenecks which must be solved during the construction. Cost implications are usually the battlefield for construction and civil engineering companies. Hence, successful companies are those that have learned how to better cut costs during the construction phase.

BUT is this a law of nature? Must it stay this way?

We don't accept it to continue in this manner!!!

The above mentioned nature of construction companies, subcontractors and sub-subcontractors, has improved significantly over the last decades, and the cost structure has dramatically changed. The economic power, that used to be placed at the construction companies' internal "civil engineering processes", are now distributed into several building blocks – for the complete construction program.

The major change has been the cost of the technical package installed in new buildings or during general renovation.

Indoor air systems play a significant role in this change of allocated building costs, and furthermore it has become the major portion in the running costs of the building during use.

Changing of paradigm

Indoor air systems have their natural structure, and one of the rules is that final adjustments and inspection of functionalities cannot be made before the building is nearly finished. The difficulties of running the indoor air installations in conjunction with heating, lighting and office equipment limit the possibilities for functional tests during construction. And partial approvals of installed systems are not an option.

Indoor air systems must be proven functional and operational when the systems and the building are in the stage of nearly being handed over to the owner or the tenants. This challenge has been addressed in many manners throughout the different building traditions in the various nations.

In the Nordic countries, we began using the quality control way, as it seems logically easy to ensure that the new European quality control systems would be functional enough to guarantee the aimed assurance of well installed and well functional indoor air systems, which would meet the aimed energy consumption, in general.

It works well in some building programs, but unfortunately not in several others. That's not good enough!!

New Methodologies are needed

The traditional systems using partial approvals and sectional acceptance are not suited for indoor air systems installed during the construction process.

It is also unlikely that several other technical systems shall always achieve their targeted functions by using this traditional methodology, that has its historical background in economic reasons that require partial payments. Such partial payments are due to be paid at specifically agreed milestones in the building program. The mechanism is ok for that purpose, of making partial payments, and it must be kept, as it works well for that purpose.

However, and as mentioned earlier, is it necessary to introduce tests that ensure that technical installations work properly in such a manner that they simulate the complete building.

Over the recent years, the term "Commissioning" has been used for such inspections and tests of technical installations. It is especially clear to everyone that indoor air systems can only be properly inspected and tested when the building construction is completed, and other installations are installed and working as well. Secondly, the influences from other installations must be carefully specified, as to ensure correct stipulation of effects, for the on-site measurements or the theoretical technical calculations.

The clever methodology of Commissioning is, in other words, inspection of installed systems, and spot checks of randomly sampled rooms and sections throughout the building - in other words, measuring the indoor air systems production of airflow, directions and energies in the air and for the transportation of that energy. The impact of the indoor air systems and the other heating and or cooling installations and the impact from windows, as to facilitate correct energy calculations - which can be scaled up for the entire building.

Using such a methodology proves to tenants and building owners that installed systems are working properly, and it verifies that energy calculations are met at satisfactory levels. Running costs has been part of the financial motivation for investing in the specific building, and they will be an everlasting bill to carry as long as the building is used. Additionally, such a methodology will clearly ensure the contractor that his component deliveries and installation work is correct. This is a new behavior, but it is at the same time also a win-win situation.

Figure 1 shows how much the energy use to run indoor climate systems varies in the European cities.

It is logic that control of indoor air flow and energy put into the air for heating and comfort is a valuable factor to be in control of, from the first day such systems are put into operation. That is a major responsibility we have at our desks.

How is it possible???

SWEDEN has been the first national market to implement a legal requirement on functional checks of the ventilation systems. Since 1991, the so called OVK (compulsory ventilation check) regulation forces the owner of a building to ensure that the ventilation system works as intended. These OVK checks must be made before the buildings are taken in daily use, and thereafter at repeated fixed intervals. The regulation states that the OVK checks must be undertaken by an officially authorized inspector – an "*OVK-besiktningsman*".

The "*Besiktningsmannen*" inspects the installations and approve it, ensuring that the legal demands are fulfilled and that the mechanical system functions are as intended. Such inspections must be undertaken when a tenant is replaced or the ownership of buildings is changed.

DENMARK is well on its way of implementing a new standard for Commissioning. It is as well an extension

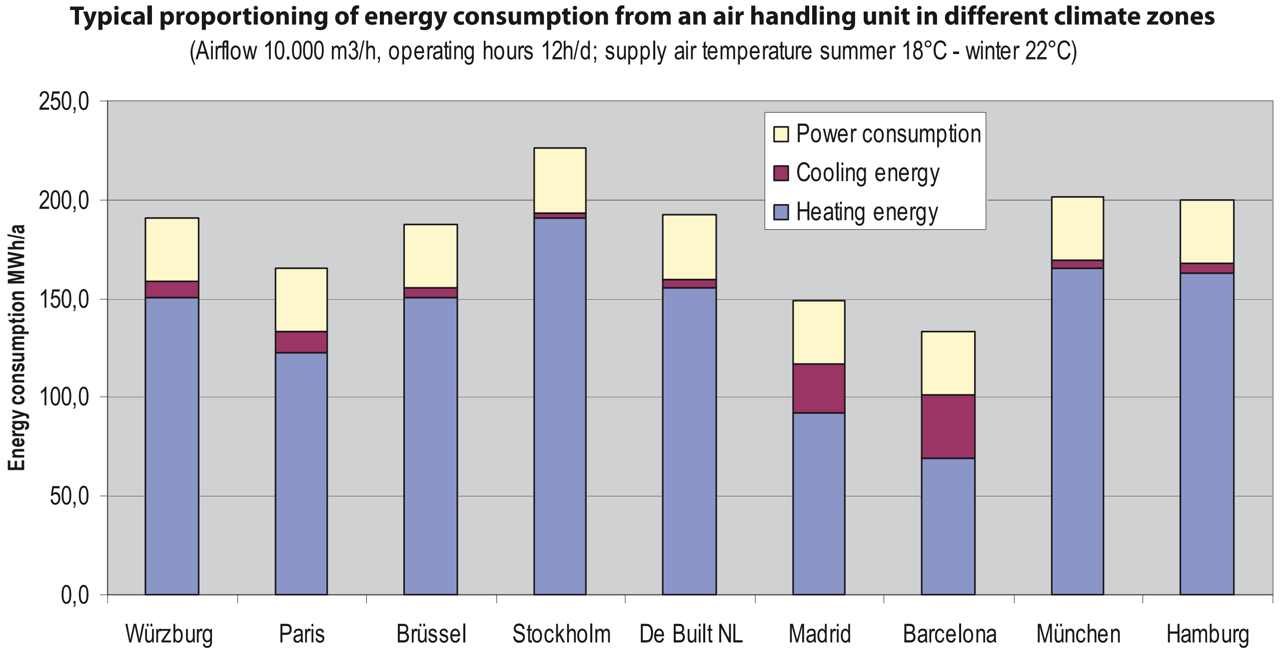

Figure 1. Example of typical energy transported through air handling units in different climates in Europe.

to the revision of the **DS447 Standard for Building Ventilation.** That revision highlighted the necessity to establish a new methodology, to ensure that the higher demands for indoor air installations are obeyed, so that heating and lighting energy improvements can be shown to be working at the end of a building process. The necessity to prove **the energy frame** is met – it is the way to ensure the demanded low energy consumption onwards, and to hold energy expenses at budgeted levels. DS447 Specifies demands for mechanical, natural and hybrid ventilation systems.

DS447 is an integrated part in the building Code.

The Energy Frame is the legal demanded level which must be met in a planned building program, and is specified by law. It is clearly expressed in the Building Regulations. The Energy Frame sets limits for energy supplied for heating, ventilation, cooling, hot water supplies and lighting. That gives for instance 52.5 kWh per m² per annum plus 1 650 kWh as a unified addition per flat.

It seems logic that such low energy levels per m² need detailed inspections of the Climate shell and the technical installations independent of each other. The inspections are only possible and/or natural in different time capsules in the building program, and demand further developments, as to be detailed enough in how new materials, building processes and completion works coincide.

It will be an issue in that process of making the new Danish Commissioning Standard to specify that, and how user behavior must be handled, and how user behavior must be linked to the commissioning report.

NORWAY has minimum requirements for **environment and health**, including indoor environment and ventilation of buildings, given in following codes:

- Technical Regulations under the Planning and Building Act added with guidelines
- The Working Environment Act with guidelines.

Demands concerning material emissions are included.

Minimum **energy performance** requirements are given in separate codes, as TEK § 14.

The minimum Energy Performance of a building is fulfilled by:

- Satisfying demands to specific solutions or
- Satisfying demands to total net energy demand (Energy frame)

A method for calculation of the energy performance of buildings is an integrated part in TEK: recommendation, NS 3031:2007+A1:2011 – Calculation of energy performance of buildings –Method and Data [1]

According to this method (with the given normative input), ventilation (incl. optional cooling) stands for 10-15% of the energy budget (net energy demand) for residential buildings, and 30–50% for non-residential buildings. Specific energy measures regarding ventilation as given in TEK are foreseen, i.e.:

- Heat recovery in ventilation plants, average temperature efficiency over a year: 80%/70%.
- Specific Fan Power in ventilation plants (SFP) :
  - □ None residential buildings: 2/1 kW/m³ s (occupied/not occupied)
  - □ Residential buildings 2,5 kW/m³ s (day and night)

It is practically mandatory to install balanced ventilation with high efficiency heat recovery.

Air tightness in new buildings of 1,5 air changes per hour at 50 Pa pressure difference (small houses 2,5).

<u>NS 3700:2010 Criteria for passive houses and low energy houses - Residential buildings</u> [2] and

<u>prNS3701 Criteria for passive houses and low energy houses – Non Residential buildings </u>[3] (in force spring 2012) indicates the level of future minimum demands in building codes.

The Norwegian Energy Certification System (ECS) [4] demands an energy certificate to be acquired for all new buildings and all buildings being sold or rented. Energy inspection of technical installations including ventilation is (with limitations in accordance with the EPBD) is required to be carried out every 4th year, with the first time within two years after handing over. The Energy inspection is a first step to minimum requirements for commissioning of technical installations.

The Norwegian Building Authority has developed a guideline [5] to perform an independent building control. New regulations regarding independent building control will enter in to force 1.7.2012.

Some examples of control items:

- Airtightness
- Energy performance
- Ventilation

In preparation for entering the new regulation regarding independent building control, prNS 8450 – Control of design and building of construction works, was launched. The document was however not accepted.

There is now a discussion on the need for development of supplementary information to the Norwegian Building Authority guidelines.

FINLAND has since 1995 an Indoor Air Classification into three classes, S1, S2 and S3, as target levels for the various uses of indoor spaces. This classification gives a possibility to define and specify higher target values than just the minimum level regulated since 1987 in part D2 of the National Building Code of Finland, which also sets some minimum requirements for ventilation system commissioning, such as an obligation to check the air tightness of ductwork and to measure supply and extract air flows, both for the whole building and for individual rooms. Revision of the Classification as well as revisions of the Finnish Building Code in 2008 and 2012 strengthened the demands of air tightness as to limit the energy used for indoor climates.

It is practically mandatory to install heat recovery in ventilation, and demands concerning material emissions are included in good indoor air design practice.

It is also to a wider extent demanded to prove air tightness in new buildings and to prove functionality of indoor air installations also in real practice.

Inspections aren't yet on the level as a commissioning will be, but improvements are been made via training of supervisors and inspectors.

The aim is to close the gaps mentioned in this article.

The gains

The aim is to establish a workable win – win environment for everyone in building programs, in a controlled way, and transparent in the working process in erecting buildings as this is works now. The new method should include the technical systems because they are, in most cases, responsible for the major share of the building initial budget, and they will cost even more during the use of the buildings during their lifetime.

Energy losses are significant in too many indoor air systems, and the ECO design initiative has only impact on the components used in the Indoor climate systems. This statement simply means that ECOdesign establishes rules for products which a manufacturer can be taken to court for if it doesn't perform as demanded in the ECO design regulative.

The EPBD sets, from the building point of view, rules for how the components in the market must be built into systems that will ensure the low energy consumption target specified for the individual building and in accordance to national and European legal demands.

We have the possibility to be frontrunners in well doing. When the good practice is one step ahead of the legal system, then this good practice can become the legal minimum, and make it possible for the legal system to understand the complexity in indoor climate systems combinations through proven experiences, meeting BAT (Best Available Technology) theories without being able to have all details controlled and steered every second. We, who have dealt with these issues in this area for a lifetime, have realized that.

In addition, numerous institutes and scientists have analyzed and evaluated which parameters need to be governed and controlled thoroughly. Both are dedicated to achieve good Indoor Air Quality, and to do it at the lowest energy use as possible.

Example: Duct air leakages

It is a common knowledge that air leakages in ducts and ductworks, in too many ventilation systems, cause severe loss of energy. It is not only loss of air, planned to be inflated in specific building sections or rooms, it is as well the energy put into that air – as for instance heating or cooling energies. The EU made an analysis, and the Fraunhofer Institute in Frankfurt took the complete analyzes to a higher level with a detailed analytic calculation. That calculation defines the loss, or waste of energy, due to simple leakage, if the average simple ductworks, which is the normality in the most systems installed during the latest 30 years, is installed. If such systems were only one class higher in tightness as to the Class B level, the savings potential are at least 15%.

- Using the energy consumption for air transport in Europe, which is statistically defined to be around 197 000 GWh/a
- 15% of that – equates to 29 550 GWh/a
- The equivalent amount of CO_2 gives (660 grams/kWh) a total of 17 730 000 ton per annum.

That analysis gives a scale of the importance of why it is necessary to use new methods in inspections and control of such systems during their lifetime, but the EC, in the recast of the EPBD, didn't introduce a requirement for the outcome of such findings to be implemented, i.e., that severe malfunctions or energy losses should they be corrected properly, within a limited period of time. It seems that the politicians didn't have the courage to demand that energy savings that have been detected throughout Europe should always be implemented.

It is sad that the indoor climate industry has been so neglected in the overall political arena, when it is a statistical evidence, from all formal statistical annual analyses, that energy used in buildings is approximately 40% of all energy used, compared to transport, that counts for 28% of the energy used. The society and politicians pay attention to the 28% and don't find means or aims in how the larger portion, the 40% consumed in buildings, can be reduced. The components are on the market and in the warehouses, but legal actions – similar to what is normal for transport – cannot be highlighted in the political agenda.

Tight buildings reduce energy losses, but require controlled ventilation and heating installations as to secure proper indoor air quality for users. We need to adjust accordingly to reach that, via intelligent new methods in the manner and systems we will be using in the future.

And the indoor climate industry must join forces in the marketplace and the political arena to convey the knowledge we have to the decision makers.

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Natural and hybrid ventilation principles based on buoyancy, sun and wind

Peter van den Engel
Delft University of Technology and
Deerns consulting engineers
p.vd.engel@deerns.nl

Remco Kemperman
Delft University of Technology and
Deerns consulting engineers

Heleen Doolaard
Delft University of Technology and
Deerns consulting engineers

Abstract

An outline is given of basic design principles or natural and hybrid ventilation related to a moderate climate such as in the Netherlands. Experiences from the past should be used to improve the design of naturally and hybrid ventilated buildings in order to improve the confidence in these systems. However, with a better use of buoyancy, wind and sun, the combined pressure-differences can be increased, which will result in a more robust system. The potential improvements of these natural forces are explored with CFD- and mass-flow-simulations. The simulation results of an advanced designed naturally ventilated building are discussed. The results show that the reduction of fan-energy can be substantial which could be applied on low-pressure mechanical ventilated buildings as well. The results of the research can be applied on new as well as on existing, to refurbish buildings.

This research is inspired by and based on the research project "Earth, Wind & Fire – Air-conditioning powered by Nature" (Bronsema 2010).

Introduction

General

Natural and hybrid ventilation systems have many advantages and, used in an advanced way, will lead to:

- more satisfied occupants;
- better air quality;
- less energy consumption.

Many studies show that more or less advanced natural of hybrid ventilated buildings have a higher occupant satisfaction than mechanical ventilated buildings. Another advantage is reduced energy consumption (Bordass, 2001, Hellwig, 2006, Brager, 2008). However, it is not always clear yet what the key success-factors are, because there are hybrid or natural ventilated buildings that have been adapted only due to a poor climate control (draught, too hot, poor air quality). It should also be noted that many fully air-conditioned buildings have comfort-problems as well. Consequently, for natural and hybrid ventilation systems more insight in effective design principles, better calculation models and a more robust control strategy are essential.

More satisfied occupants

Advanced designed natural or hybrid ventilated buildings have the potential of a high appreciation by the occupants. Especially operable windows are essential, not only for physical but also for psychological reasons. The direct supply of outdoor air can lead to the following improvements:

- Improving air quality, depending on the local environment of the building.
- Cooling of the building, by using the outdoor temperature.
- Increasing the local and average air velocity, when the indoor temperature is high (comfort cooling).

Occupant satisfaction is one of the starting points of the design of buildings with second skin façades. In building certification systems like BREEAM and LEEDS operable windows will receive special credits. In the program of requirements of the Dutch Government Buildings Agency operable windows are already design-standard for years.

Better air quality

Air quality can be measured by assessing the CO_2-levels, but there are other important physical and subjective elements as well, such as the scent of a tree or the experience of nature. Much of it is difficult if not impossible to measure.

Less energy consumption

Fan-energy contributes, together with energy of appliances and lighting, for a major part to the energy-demand of a building. A well isolated and solar protected building with efficient energy generation neither need much heating nor cooling energy.

Fan energy can be reduced by:

- Reduction of the resistance of all the components of a ventilation system. An air velocity of 1–2 m/s is recommended (Gräslund, 2011).[1]
- Natural ventilation during only a part of the day or the year when the outdoor circumstances are favorable.[2]
- The design of buildings with natural air supply, exhaust or both.
- Making use of natural elements like internal or external thermal pressure differences (buoyancy), sun and wind.

The ultimate goal is a building that is, as far as possible, completely naturally ventilated with a minimum use of heating and cooling energy. This is possible by:

- Air flow control of the inlet and outlet, after measurement of the CO_2-levels, and ventilation only during working hours.
- Increase of ventilation only when the outdoor temperatures are not too high or too low.
- Heat recovery with a low air resistance, if necessary connected with a heat pump (Christensen, 2010). When the temperature-differences (between extracted and supplied heat) are low, the efficiency of the heat pump will be high.

Economy

For a cost-benefit analysis several parameters are important.

Costs will increase due to the following factors:

- Natural or hybrid ventilated buildings have very low energy consumption only if the air flows are effectively controlled. A control system is expensive.
- The size of ducts is generally larger in case of natural ventilation.
- Hybrid systems incorporate a mechanical back-up system.
- A façade with operable windows is more expensive than without. The opening of a window during a hot and humid summer day will lead to the increase of the cooling capacity of a central air handling unit. An option is a window that can be closed either automatically or by the occupant as a result of a warning signal.

Benefits are:

- Natural ventilation and operable windows will contribute to the productivity of occupants and reduce sick-leave.
- Fan and cooling energy will be reduced.
- The total length of ductwork can be reduced (depending on the design-principle).

To a new type of risk assessment

Naturally ventilated buildings are more vulnerable to air flow disturbances and draught than mechanical ventilated buildings, however, it should be noted that this is also a matter of assessment, which is often too general. Consequently, naturally ventilated buildings need a special type of risk assessment, which is not available yet. For instance, the kind of turbulence produced by a window is different from cooled mechanical supplied air. Air supplied via a window has another size and frequency distribution of eddies, which requires another kind of draught-evaluation. Moreover, the comfort-expectation of the occupants can be different.

Points of attention

General points of attention are:

- In a completely naturally ventilated building a single operable window may disturb the whole ventilation system due to the large air flows when the pressure-differences are high. However, when the air quality of a building compartment as a whole remains well, a different air flow pattern will not always be a problem.
- Mechanical systems are often able to solve air pressures due to open windows, but it is not always clear enough what the real limitations are. What are acceptable pressure differences?
- In natural ventilated buildings an operable window will not interfere with other fresh-air flows when a building compartment or space has its own air inlet and exhaust (Short, 2004).

1 For natural systems a velocity 0.5 m/s is most adequate for the primarily design stage (Lomas, 2007). Critical elements are filters, sound-absorbing air ducts and heat-recovery systems. However, these elements can be integrated in natural systems as well.

2 This is the common occupant behavior with operable window, but windows are not always intelligent designed for both large and minimum air flows.

- In office landscapes not all persons are equally sensitive to draught by operable windows, so when occupants can choose their working place in accordance with their sensibility to draught there is less risk.
- Cold supplied outdoor air may produce draught. Depending on the amount of supplied air, inlet temperature and mixing qualities there may be draught or not.
- An inlet can become an outlet at the top of the building; however, a separate exhaust-system can prevent this.
- The air-tightness of the façade needs enough attention, which is often overlooked.

Natural ventilation principles

Hybrid ventilated buildings are difficult to compare. Air supplies or exhausts may be centralized or decentralized. Apart from the chosen system there is a varied use of natural forces, like buoyancy, wind and sun.

The most important different types of ventilation are: (1) decentralized supply and central exhaust, (2) central supply and decentralized exhaust and (3) central supply and central exhaust.

Additionally, there are all kinds of combinations possible with mechanical ventilation and cooling. Moreover, the way of local ventilation may vary as well, with mixing or displacement ventilation as the most obvious differences. When displacement ventilation is applied it will always be necessary to warm the air to near room-temperature. In the long run economical and practical issues will determine as well which system will be applied.

Physical principles

General

Buoyancy or the stack-effect is the most important driving force of natural ventilation being to a large extend sufficient to ventilate a building. Interesting is the self-regulating effect of buoyancy: the higher the heat load of the building, the larger will be the air flow and cooling effect of natural supplied and exhausted air. Recently several buildings have been designed that make use of this principle (Lomas, 2007), but even those buildings make use of positive wind-pressures in the inlet-plenum.

In a hot and moderate climate extra heating of the chimney or cooling is necessary during some periods of the year.

However, for a moderate climate with a modest internal and external heat load the use of other natural forces like sun and wind may be required as well in order to create higher pressure differences in certain periods of the year. For instance, when the desired low indoor temperatures in summer are achieved, the stack-effect will be reduced. Buildings with natural air supply via the façade can suffer from high negative pressures on the façade, which differ from systems with natural air supply via a central atrium. Heat recovery in the exhaust may be required in order to minimize heating and cooling energy, but this depends on effectiveness of the airflow-control strategy as well.

Buoyancy

Buildings that are ventilated via atria and shafts have more options to use wind-pressure in a positive way. Buoyancy is effective when the inside temperature is higher than the outside temperature. Cool outdoor air with a higher density will replace hotter air with a lower density. In principle, internal heat sources are sufficient to ventilate a building. However, in the cooling season with lower pressure differences, there is in an increased risk of a return flow of air. Buoyancy can be increased by the height of a shaft, the temperature in the shaft or a lower pressure in the shaft due to wind. Another option is a building-design where return-flows are just another way of ventilation.

Wind

Wind is almost always available, but an effective usage is often misunderstood. Coastal areas have more wind. The wind-pressure depends on the height of the building related to the surrounding buildings. The under-pressure is generally the lowest above the roof of a building. This can be increased by the shape of building and exhausts. Options are a venturi-shaped outlet or a cowl-system (Khan, 2008, Blocken, 2011). The under-pressure above a roof should always be lower than the pressure on the inlets.

Sun

High outdoor temperatures go always together with much sunshine. In periods with a low buoyancy force, the sun can overtake the role of buoyancy and can heat the exhaust-duct or transfers its power to a fan via a PV-system.

Simulations

General

In CFD (Phoenics) and TRNSYS/TrnFlow a model is developed. Also a building with a central air supply and central exhaust is simulated.

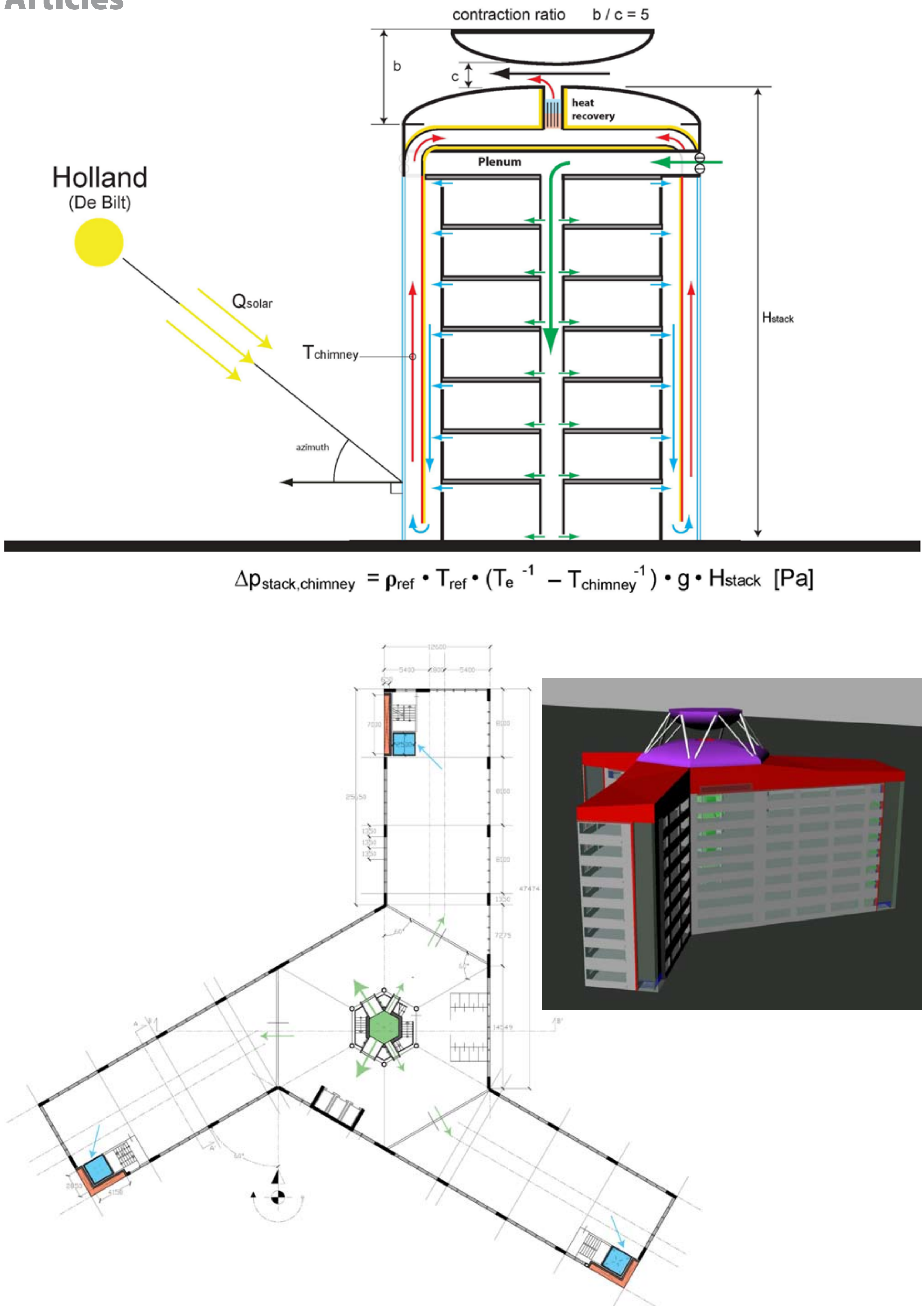
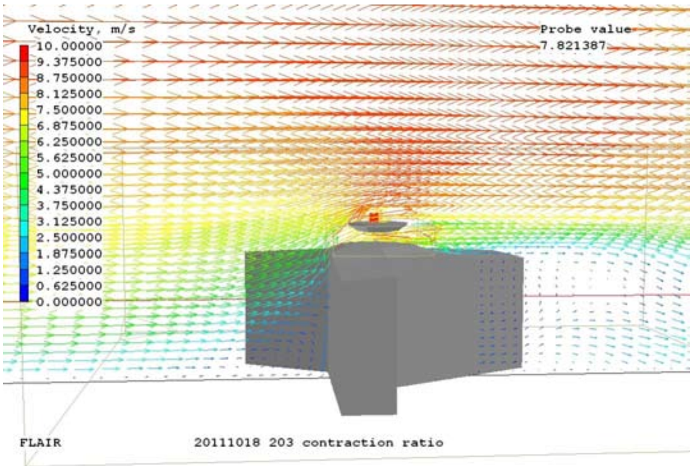
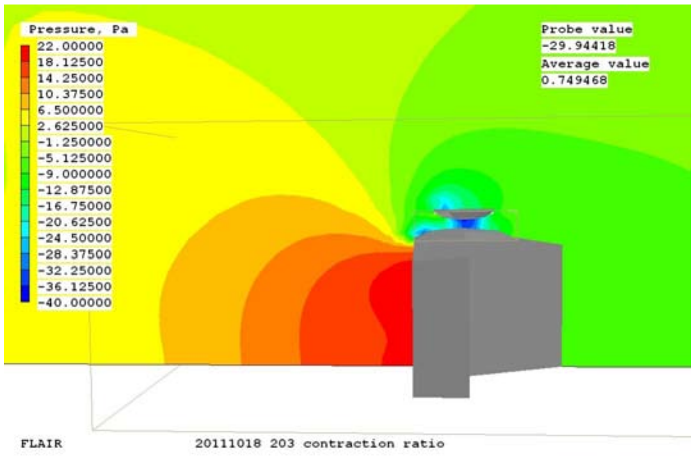


Figure 1. Diagram of the basic-TRNSYS/TrnFlow-calculation model evaluated in CFD (Phoenics) as well. Moreover, other chimney-types are evaluated, see Figure 2 and 3.

Increased under-pressure due to the venturi-effect in case of a centralized chimney

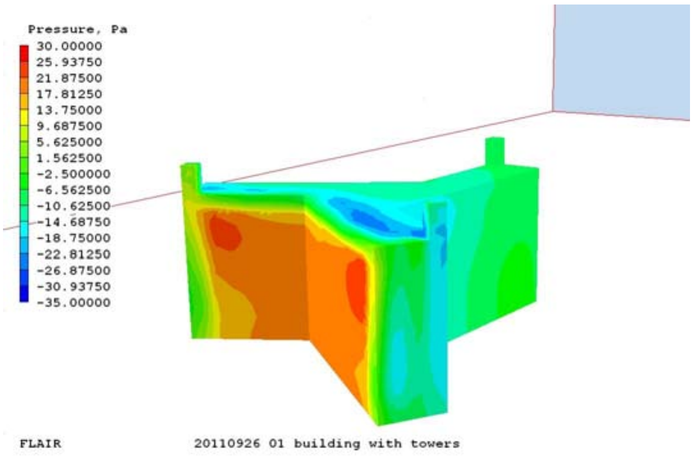


a. The velocity of 5 m/s is increased to circa 8 m/s due to the shape of the roof.

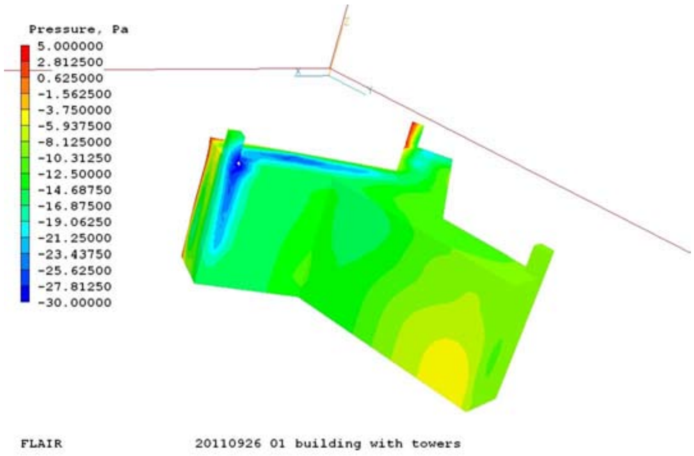


b. The resulting under-pressure is 30 Pa.

Over- and under-pressure of decentralized chimneys



c. Zone with overpressure for air inlets.
This is about 2 m below the rooftop.



d. Under-pressure of decentralized chimneys, integrated in the façade, which can be used as solar chimneys as well.

Figure 2. Advanced use of over- and under-pressure for natural ventilation systems, several options.

The following setpoints and parameters are used:

- Minimum temperature 20°C
- Maximum temperature 25°C
- Opening of the building from 7:00 am – 19:00 pm
- The ventilation system is shut off when the building is not in use
- Internal heat load 35 W/m²
- Insulation closed parts of the façade U = 0.23 W/m²K
- Insulation glass + window-frame U = 1.6 W/m²K, g-value = 0.67
- Glass percentage 30%
- Sunshade, g-value = 0.40
- Infiltration rate 0.1 h
- Ventilation, > 50 m³/h per person
- Size of the building 13,050 m² gross floor area
- Size of the solar collector, width 7 m, height 28.5 m (East, South and West)

CFD-results

The exhaust system has one or three chimneys. The position of the air inlet is near the top of the building in a

Table 1. Air flows and total driving pressure differences for the different storeys [required $Q_v = 0.5\ m^3/s$ per office floor]

Storey	Average Maximum air flow	Average air flow	Relative Standard Deviation	Average maximum driving pressure difference	Average minimum driving pressure difference	Average driving pressure difference	Relative Standard Deviation
	[m³/s]	[m³/s]	[%]	[Pa]	[Pa]	[Pa]	[%]
0th	3.19	1.26	28	329	3.3	39.3	70
1st	3.03	1.16	29	326	4.0	39.4	69
2nd	2.79	1.03	30	329	4.1	39.4	69
3rd	2.59	0.92	31	328	4.0	39.4	69
4th	2,91	0.98	33	329	4.0	39.5	69
5th	3.15	1.00	36	329	3.9	39.6	69
6th	3.22	0.95	41	330	3.8	39.6	69
7th	3.29	0.88	49	331	3.8	39.8	69
average		**1.02**				**39.6**	

Table 2. Part of occupation time with sufficient ventilation [$Q_v > 0.5\ m^3/s$ per office floor]

Storey	North wing W orientation of solar chimney	South-East wing SW-SE orientation of solar chimney	South-West wing SE-SW orientation of solar chimney
	[%]	[%]	[%]
0th	99.3	99.5	99.5
1st	99.1	99.3	99.3
2nd	98.3	98.8	98.7
3rd	96.8	97.7	97.4
4th	97.8	98.6	98.4
5th	97.7	98.7	98.4
6th	93,5	97.0	95.8
7th	78.1	86.7	83.7
average	**95.1**	**97.0**	**97.0**

Table 3. Energy consumption.

	Heating energy [MJ/(m²·y)]		Gas consumption for heating[m³/(m²·y)]
Building total	226.9		7.2
Fan energy consumption			
Building case	Fan energy consumption building case [kWh]	Fan energy consumption in 100% mechanical drive case [kWh]	Energy savings relative to 100% mechanical drive case [%]
Buoyancy, wind and sun 10 Pa	11	927	99
Sustainable (low pressure system) 200 Pa	10,635	18,792	43
Conventional 1.000 Pa	75,796	93,960	20

Table 4. Average driving pressures of physical elements.

	Average Total driving pressure, average storey	Buoyancy, average storey	Wind, average storey	Solar contribution to stack pressure in a solar chimney with South-East/ South-West orientation, average storey
ΔP average [Pa]	39.6	19.6	18.5	2.1
Pa > 0 during occupation [%]	100.0	98.2	100.0	71.2
Pa > 5 during occupation [%]	99.9	92.1	62.0	12.3
Pa > 10 during occupation [%]	98.0	79.4	45.4	0.3
Pa > 20 during occupation [%]	80.1	47.2	30.0	0.0

Table 5. Contribution to the driving pressure of the individual components.

	Stack pressure in Solar chimney plus shunt duct South-East / South-West orientation	Solar contribution to stack pressure in a solar chimney plus shunt duct South-East / South-West orientation	Under pressure on exhaust due to 'venturi' roof	Under pressure on exhaust due to local 'venturi' exhausts directly on the chimneys
ΔP average [Pa]	21.7	2.1	18.3	9.2
Pa > 0 during occupation [%]	100	72	100	100
Pa > 5 during occupation [%]	98	17	68	51
Pa > 10 during occupation [%]	89	0	51	31
Pa > 20 during occupation [%]	55	0	31	13

zone with overpressure (**Figure 2c**). The position of the exhaust on the roof is in the centre or near the façade. The under-pressure in the exhaust can be increased by a venture-shape (**Figure 2a and b**). The exhaust system can – if located near a façade – make use of solar energy as well.

The CFD-simulations show that near the centre of the building there is always the possibility to add an inlet with a positive pressure.[3]

TRNSYS/TrnFlow-results

Table 1 shows that the average pressure difference is circa 39 Pa, which makes it more interesting to add other components such as heat recovery or electrostatic filters.

From **Table 1 and 2** can be concluded that the building is on average 2 times over-ventilated and with a maximum of circa 6 times. This is due to the combination of very low outdoor- temperatures and much wind.

3 The low pressures near the roof may partly be the effect of the coarse grid of CFD-simulation.

In order to reduce the complexity of the simulation-model, the openings are designed with a fixed size. This results in relatively high air flows in winter with outside temperatures around zero. Another point of attention is simultaneously reduction of heating and cooling. Additional reduction of energy is possible with heat recovery in the exhaust.

With a better flow- and temperature-control and heat recovery the calculated heating energy of 7 m^3 natural gas equivalent per m^2/y (**Table 3**) could be reduced significantly and will probably result in a heat consumption close to the passive standard of 1.5 m^3 natural gas equivalent per m^2/y.

However, one of the most striking improvements of natural ventilation is the reduction of fan energy. Most of the energy-savings are possible when a high pressure ventilation-system is changed in a low pressure system (Gräslund, 2008). Comparing a mechanical ventilated building with a very low pressure-difference of 10 Pa, natural ventilation with a solar chimney and a venturi-roof, can reduce the energy consumption already with 99%. Comparing a low pressure mechanical system of

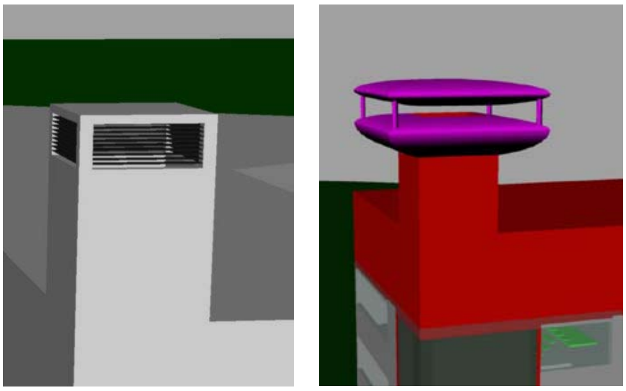


Figure 3. Two options of decentralized chimneys. The venturi-shape gives the best results.

200 Pa the savings are still substantial (43%). Finally, the application of solar chimneys and a venturi-roof can reduce the energy consumption of a 1,000 Pa (improved standard) system with 20% (**Table 3**).

The following table presents what the contribution is of buoyancy, wind and sun separately related to the required pressure difference in the system:

When a decentralized venturi-roof (**Figure 3**) is applied the positive effect of the wind will be smaller, but will still be significant.

The contribution of buoyancy, wind and sun on the different components are presented in more details in **Table 5**. 3ε

Discussion

1. The research shows the high capacity of natural forces to reduce fan-energy, even for completely mechanical driven systems.

2. Most of the savings are possible by designing a low pressure ventilation-system.

3. For a medium sized building in a moderate climate an average natural pressure difference of 39 Pa is achievable. The contribution of each of the forces has to be assessed individually.

4. Depending on the control-qualities of the ventilation-system, and the availability of heat recovery, a low energy consumption for heating and cooling is possible, near the level of passive-standards. In order to assess this in detail more research will be required.

5. Integration of operable windows still needs more attention. Design-possibilities are return valves, more flow-controllers in the system or separate inlets and exhausts for each building compartment (Short, 2004).

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This summary is based on the work of the winner, R.Maaijen, at REHVA student competition in Timisoara during REHVA Annual meeting, 2012. The full length article with the references is available at the journal website, http://www.rehva.eu/en/rehva-european-hvac-journal.

Human centered energy control: taking the occupancy in the control loop of building systems

Ir. R. Maaijen,[1] Prof. Ir. W. Zeiler,[1] Ir. G. Boxem & PDEng. Ir. W. Maassen[2]

[1]Technische Universiteit Eindhoven, Faculty of the Built Environment, Unit Building Physics and Services, Eindhoven

[2]Royal Haskoning Consulting Engineers, Rotterdam

Introduction

Traditional comfort control focusses on indoor temperature regulation with a uniform thermal environment. Due to individual differences it is not possible to provide an optimal perceived comfort level to all office workers. In response of discomfort, the building user performs actions to restore his individual comfort. An undesired effect of these actions is that the energy use of the building comfort systems often increases. We present a new HVAC control strategy based on the actual demand and indoor localization of the individual building user. In this way we supply energy for comfort only to those positions where needed. With critical performance indicators we looked for the most important parameter (e.g. human actions and building parameters) on building comfort and energy performances. The objective of this critical performance indicator process control strategy is to reduce the energy demand, while maintaining thermal comfort of the individual building occupant. With our new approach nearly 30% energy savings can be achieved on heating demand and up to 38% energy savings on cooling demand compared with current energy demand.

The satisfaction of the occupants with their thermal environment mainly determines the success of the application of HVAC systems. However, in practice the intended energy efficiency as well as comfort level of these HVAC systems is not achieved, resulting in more sickness absence, lower productivity and higher energy costs. To meet the demand for both a more comfortable indoor environment and building energy savings, it is necessary to implement knowledge of the building user in the building comfort control strategy.

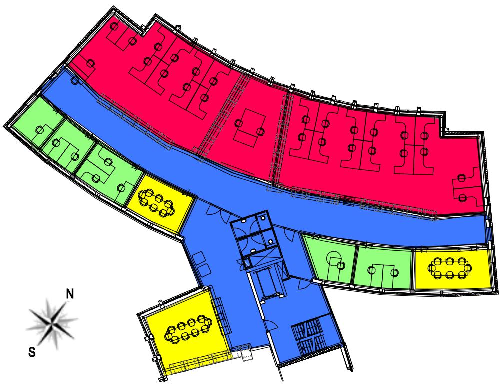
Human in the loop

To achieve the savings it is necessary that the HVAC systems automatically adapts to the actual individual needs. This requires a method where the user with his individual needs is included in the control loop of building comfort systems. Within this research this method is called the 'human in the loop approach'. Literature shows that workplaces in office buildings are unoccupied for a large percentage of time, and differ between buildings [Mahdavi et al., 2011].

The idea is that when the actual need for comfort of the individual building user is addressed, this will lead to reduction of the energy consumption by the building systems. Thereby, the control objective is to look how the individual building occupants use their building and if commonly used occupancy spots can be recognized. RFID technology is proposed for building user indoor locating system, because of its accuracy for location estimation and possibilities for identification of the user [Li et al., 2012].

The case building

The aim was to assess the energy saving potential when anticipating on the human influences by sending energy only to those spots where energy is needed to change the thermal conditions. Therefore the building occupant needs to be included in the control loop of building services.



Properties	
meeting room	(yellow)
open-plan office	(red)
corridor/staircase	(blue)
cell office	(green)
Year of completion	2006
Floor surface	ca. 500 m²
Employees	ca. 35 persons
Type workplace	flexible office space
Type of work	computer / desk work, design, calculation
HVAC system	district heating, cooling machine
room conditioning	induction unit
HVAC control	room level

Figure 1. Floor plan of the case study floor (A) with the important properties of the floor (B) and a picture of the building from the outside (C).

This research used a real building and user's behaviour: measurements were performed on the fourth floor of Royal Haskoning, an international engineering consulting company in The Netherlands, Rotterdam (**Figure 1**).

Low-budget wireless sensor networks with portable nodes show high potential for real-time localization and monitoring of building occupants [Feldmeier and Paradiso 2010]. Therefore static wireless sensor nodes were mounted on the floor and communicate with mobile nodes (or in the future smartphones) carried by the occupant to determine the position of the occupant on workplace level.

The wireless static nodes for position tracking of the occupants were placed on points of interest e.g. the workplaces, printer, coffee machine and toilet. Based on the signal strength the nodes locate in which zone the occupant is. With the nodes a mesh is created consisting of 30 zones.

Figure 2. Occupancy intensity as percentage of the most occupied workplace, showing two hotspots and increased activity around the toilet, coffee machine and printer.

Results

The measurement results were obtained for six weeks during winter period. During this period most of the occupants of the floor (20 employees) wore a node for localization. The average occupancy of the employees was approximately 40%. Occupancy hotspots can be distinguished as shown in **Figure 2**. The amount of time of occupants being present in a zone is summed over the whole period. There are obvious favorite workplaces and higher occupancy intensities around the coffee machine, toilet and printer.

Appliances

The use of electrical appliances is the most influencing variable on building performance. In previous research Parys concluded that the operation of office equipment is obviously not driven by indoor environmental quality motives. Therefore it is more logical to link the ratio of internal heat gains over the nominal power of office equipment to the occupancy rate. [Parys et al. 2011]

When the averaged profiles for occupancy and use of electrical appliances are looked into, there is a strong correlation between them with a determination coefficient of 0.94. Looking at workplace level there is no clear correlation. This is proved by **Figure 3** with the occupancy and appliance use for two reference days. Connections are visible, but the appliance use does not correlate with the occupancy.

Energy saving potential

Data of the measurements are applied in a simulation to determine the energy savings potential compared to the designed energy demand. Three variations can be distinguished, B. the actual energy demand, C. send energy to spots only when needed (human in the loop) on room level and D. human in the loop on workplace level with individual climate control. The obtained energy saving potential by the profiles for the three situations is shown in **Figure 4**. The measurements were during the winter, when there was only a heating demand. The acquired profiles for electrical appliances use and occupancy patterns are also applied in the summer situation. A sensitivity analysis is established by applying the standard deviation of the different profiles to the model, to ground the reliability of the results.

Conclusions

Big steps need to be made to reach future targets regarding energy consumption and comfort level in the built environment. With increasing energy performances, the influence of the occupant becomes significant and should be looked into. In the used case study the human influence is 3-5 times higher than variations in building parameters. With the human in the loop approach energy is only sent to those spots where needed by localizing the building occupant and anticipating on its influences. From measurements of 20 employees during 6 weeks on an office floor it is clear that occupancy hotspots can be distinguished.

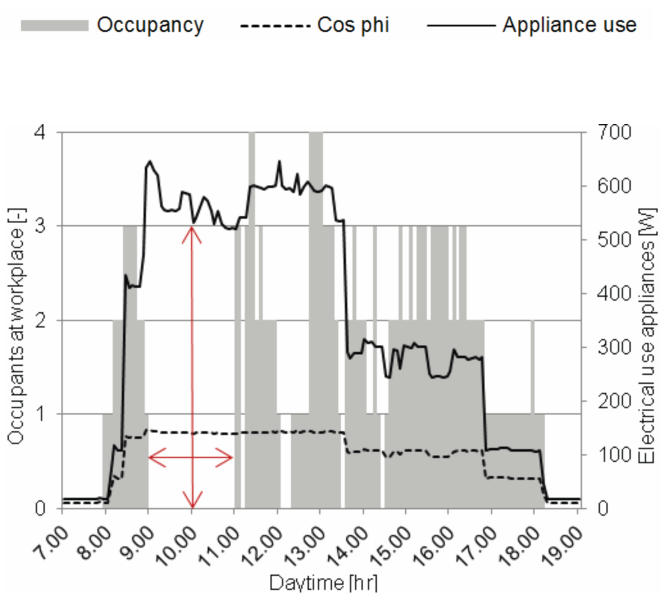


Figure 3. Occupancy for 4 workplaces and total energy demand for those places for a reference day, time step = 5 minutes. The red arrows indicate that energy demand can be reduced when the occupants are not at their workplace.

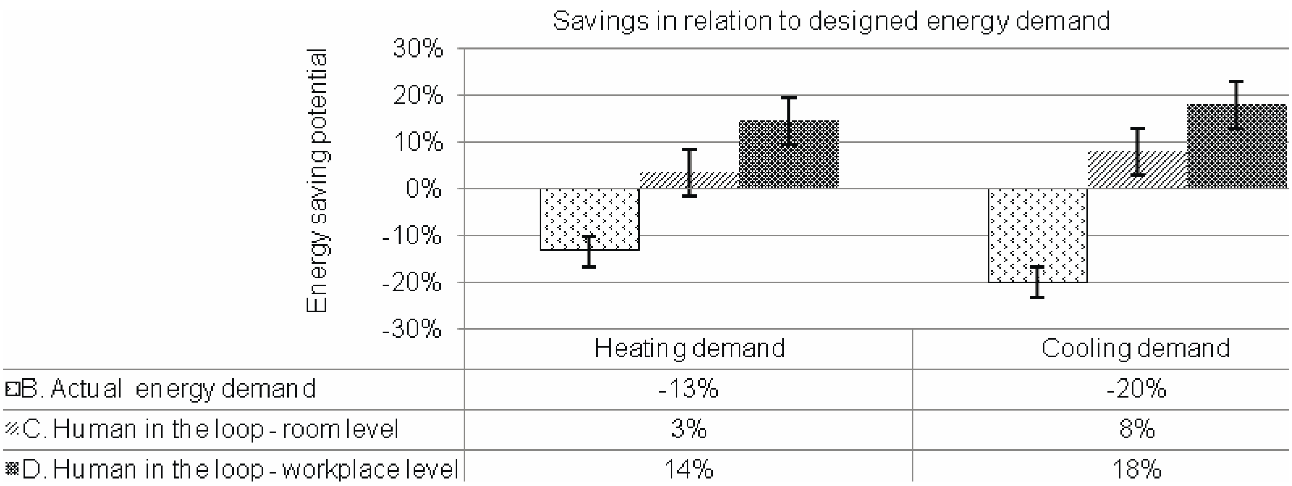


Figure 4. Energy savings compared to designed energy demand for actual energy demand (B), energy control on room level (C) and sending energy to the individual on workplace level (D).

A strong correlation between the occupancy and the most important human influence on building performances, use of electrical appliances, is shown on floor level. However, on workplace level a relation can be noticed, but lets a lot of space for decrease of the energy demand / internal heat gains. Further research towards possibilities and advantages is needed.

With the human in the loop approach more than 20% energy savings can be achieved on heating demand and up to 40% energy savings on cooling demand compared with the actual energy demand. 3E

New IAQ sensor for demand controlled ventilation

Simone Herberger
Dipl.-Chem.
AppliedSensor GmbH, Germany
simone.herberger@appliedsensor.com

Heiko Ulmer
Dr.
AppliedSensor GmbH, Germany

People spend ~90% of their lifetime indoors and providing the right environment takes energy and resources. Many efforts have been undertaken to reduce energy consumption of buildings and today's regulations require strict airtightness of buildings. In parallel to the improvements of the building envelope, the request for sufficient and energy-efficient ventilation increased. Energy-efficient ventilation schemes have to be applied as heat losses caused by ventilation are getting more and more pronounced in conjunction with reduction of the overall energy demand of buildings. Several studies of today's airtight buildings showed that sufficient ventilation is necessary to provide a healthy and comfortable indoor environment and to maintain building integrity. Measures to improve indoor air quality are cost-effective, considering potential benefits of reduced sick leave, reduced medical costs and better performance at work gained at improved indoor air quality.

Today's ventilation schemes are mainly based on time-scheduled ventilation. However, fixed ventilation schemes often do not account for the right ventilation demand and can lead to a waste of energy. More advanced active systems apply demand controlled ventilation (DCV) using sensors for indoor air quality (IAQ) control. Bad IAQ is often related to humans and their bio-effluents and the most common indicator is carbon dioxide (CO_2), whose production is proportional to the human metabolic rate. Nevertheless, the use of CO_2 as indicator and state-of-the-art sensors for CO_2 quantification, mainly based on non-dispersive infrared adsorption technology, are limited. Events coming along with more complex mixtures of gaseous compounds, mainly volatile organic compounds (VOCs), released by human bio-effluents, cooking odours, outdoor pollutants, cleaning supplies as well as building material and furniture emissions, cannot be detected with CO_2 as indicator, but play a pronounced role for human air quality perception and some are even a hazard to human health.

AppliedSensor

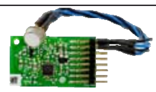
AppliedSensor is an international supplier of gas sensing solutions for air quality, comfort, control and safety applications. Improved reproducibility and stability together with low cost potential led to application-driven developments of micro-machined metal oxide semiconductor (MOS) gas sensors for industrial and commercial products in everyday life.

Intelligent Indoor Air Quality Monitoring beyond CO_2

AppliedSensor developed a family of low-cost and compact products for IAQ monitoring and energy-efficent DCV (**Table 1**). These sensor modules close the gap between direct CO_2 and VOC only detection. The detection of relevant indoor VOCs and potentially harmful substances (e.g. CO) is faciliated by the MOS sensing element. An empirical algorithm correlating proportionality of CO_2 production rate and metabolic VOC generation allows the iAQ-modules to provide measures of both, CO_2 and VOC related events at the same time, and makes the modules applicable in almost every indoor environment. The correlation between human CO_2 and VOC production provides a standardized output signal in CO_2 equivalent units [ppm] according to the request of HVAC planners and ventilation standards refering DCV settings to CO_2 concentrations above outdoors.

The professional iAQ-modules (iAQ-100, iAQ-2000, iAQ-engine, iAQ-Duct Kit) can be used for exhaust/supply air flow control in suitable centralized and decentralized ventilation systems and for automatic window

Table 1. AppliedSensor's iAQ modules.

Sensor modules		Measurement range	Interface	Dimension/weight	Characteristics
iAQ-2000		450-2000 ppm CO_2-eqivalents	I²C, 0-5 V, PWM, RS232	43 x 22 x 7 mm/4 g	Broad application range
iAQ-engine			I²C, 0-5 V	17 x 10 x 4 mm/3 g	Smallest design
iAQ-100			PWM	56 x 29 x 14 mm/10 g	Protection class IP 67
iAQ-Duct Kit			I²C, 0-5 V, PWM	43 x 22 x 7 mm/4 g	iAQ-2000 with cable, sensor on TO39 for probe-tip integration
iAM			USB	-	Personal IAQ monitor enables manual ventilation

actuation. In addition, AppliedSensor offers the personal indoor air quality monitor (iAM). Plugged to the computer or USB adapter the iAM makes building occupants aware of indoor air conditions signaling ventilation demand by three LEDs (green, yellow, red). The application software can be downloaded from www.appliedsensor.com.

Field Studies – VOC vs. CO2 Approach

The developed iAQ-modules have been optimized based on case studies in a variety of environments such as offices, meeting rooms, schools, kitchens, restrooms and bedrooms.

The benefit of VOC-based IAQ control compared to CO_2-based DCV becomes obvious in indoor spaces where changes of CO_2 are too small for ventilation control but indoor air is dominated by odorous events, affecting perceived air quality to a large extent (e.g. kitchens, restrooms, smoking areas). The iAQ-module allows capture of CO_2 concentrations and odorous events at the same time, whereas NDIR sensors are only able to measure the CO_2 production linked to the grade of occupancy. The main signals caused by cooking activities, that can be attributed to VOCs are only detected by the iAQ-module in the background of CO_2 (**Figure 1**, right hand side: cooking event).

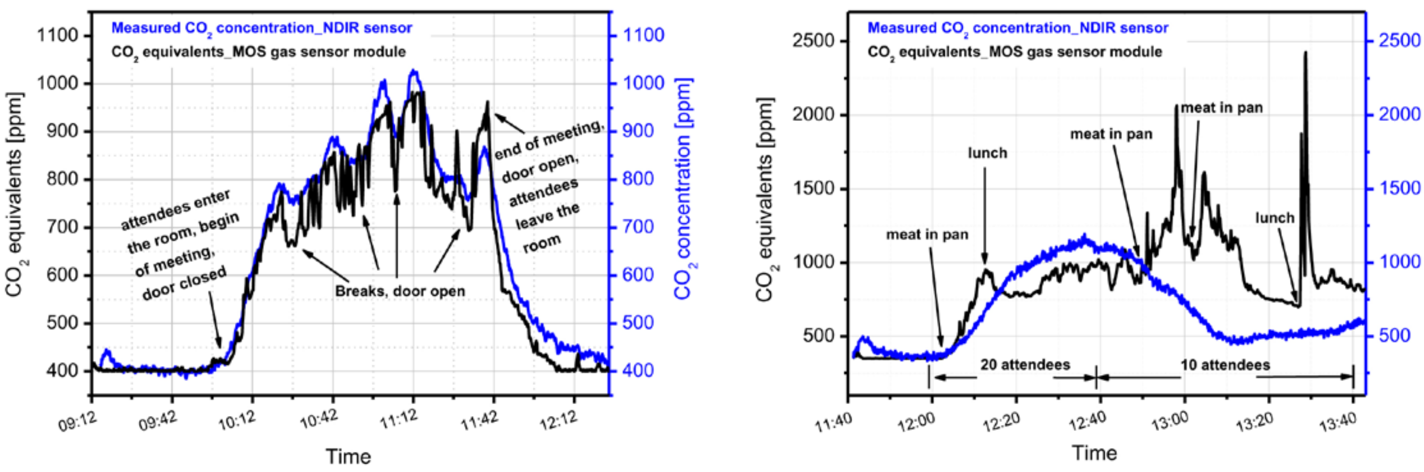


Figure 1. VOC vs. CO_2 approach: predicted and measured CO_2 concentrations (meeting room/kitchen).

Implementation of the empirical algorithm for CO_2 prediction based on anthropogenic VOC detection allows reliable correlation of predicted and measured CO_2 concentrations in indoor spaces where no appreciable human activity takes place. The perfect correlation of predicted CO_2 equivalents calculated from the detected VOC level compared to the measured CO_2 concentration using NDIR technology is shown by means of a meeting room on the left hand side of **Figure 1**.

Long-term stability

For long-term stabilty testing, iAQ-modules are permanently operated in the field for more than seven years. Real-life tests comparing long-term operated modules with new sensor modules showed, that perfect functionality in the field is guaranteed even for iAQ-modules with more than 60.000 operating hours (**Figure 2**).

Best practice examples

DCV - office

The iAQ-modules have been tested in various centralized and decentralized commercial ventilation systems for DCV. The main focus has been on energy demand and resulting IAQ compared to natural and time-scheduled ventilation. DCV ensures that fresh air is supplied to interior spaces whenever necessary. When defined threshold limits are exceeded, the module alerts the climate control system to increase ventilation. When VOC levels are minimized, the module instructs the system to decrease ventilation, thereby saving energy and lowering building operation costs.

The results when triggering the supply air rate with the iAQ module instead of applying time-scheduled ventilation are very promising: In a 80 m³ office with two employees, the supply air rate could be reduced by 60% compared to time-scheduled ventilation according to DIN EN 15251 (**Figure 3**, left hand side) while maintainig good air quality (CO_2 concentrations did not exceed 1000 ppm for the design value of 2 people in the office). The ventilation settings can be taken from **Table 2**.

Table 2. Ventilation settings - office.

Ventilation Strategy	Description
Time-scheduled ventilation	Ventilation according to EN 15251 (assuming IAQ category II, low polluting building material and equipment, 2 attendees) • Total air flow rate: 125 m³/h (Mo-Fr 08:00 a.m. to 06:00 p.m.) • 6 m³/h otherwise
DCV using iAQ-module	Sensor output, 450-2000 ppm CO_2 equivalents serves to trigger the ventilation rate in linear scale from 6 m³/h to 125 m³/h

60% less supply air resulted in 70% less power consumption for the fan and 15% less heating energy demand during heating period 2009/2010 (**Figure 3**, right hand side).

DCV - meeting room

In a highly frequented meeting room designed for 8 people and time-scheduled centralized ventilation of 70 l/s from 08:00 a.m. to 6 p.m., 50% supply air rate could be saved within one week applying a 3-step DCV scheme

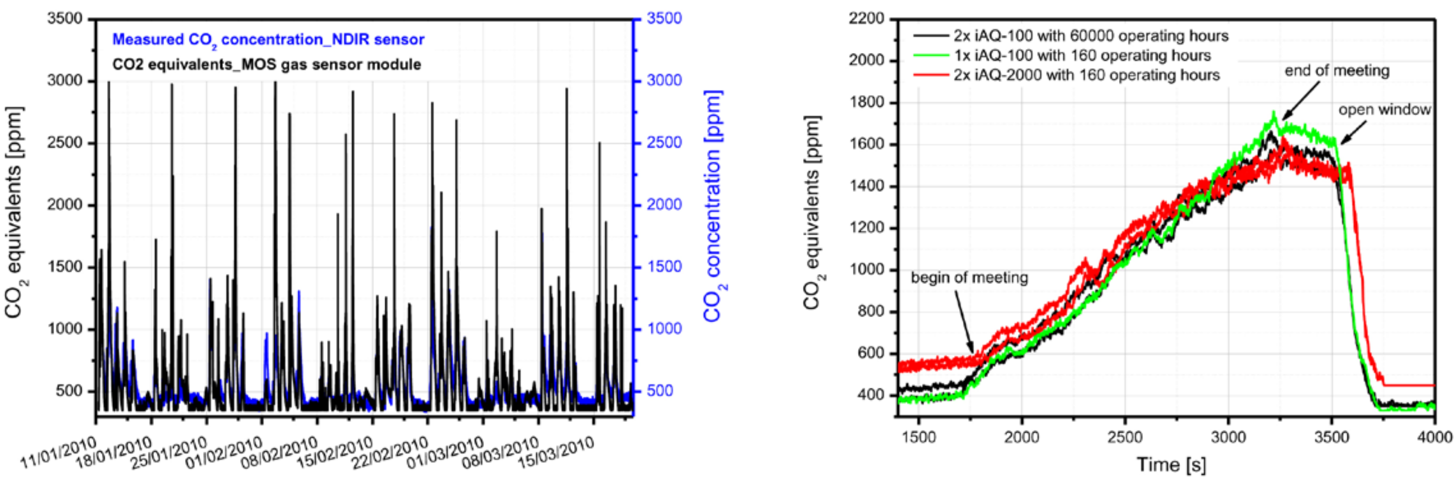


Figure 2. Long-term stability: Left: 10 weeks IAQ monitoring data of permanently operated iAQ-2000 module. Right: Real-life test after 60.000 operating hours (iAQ-100).

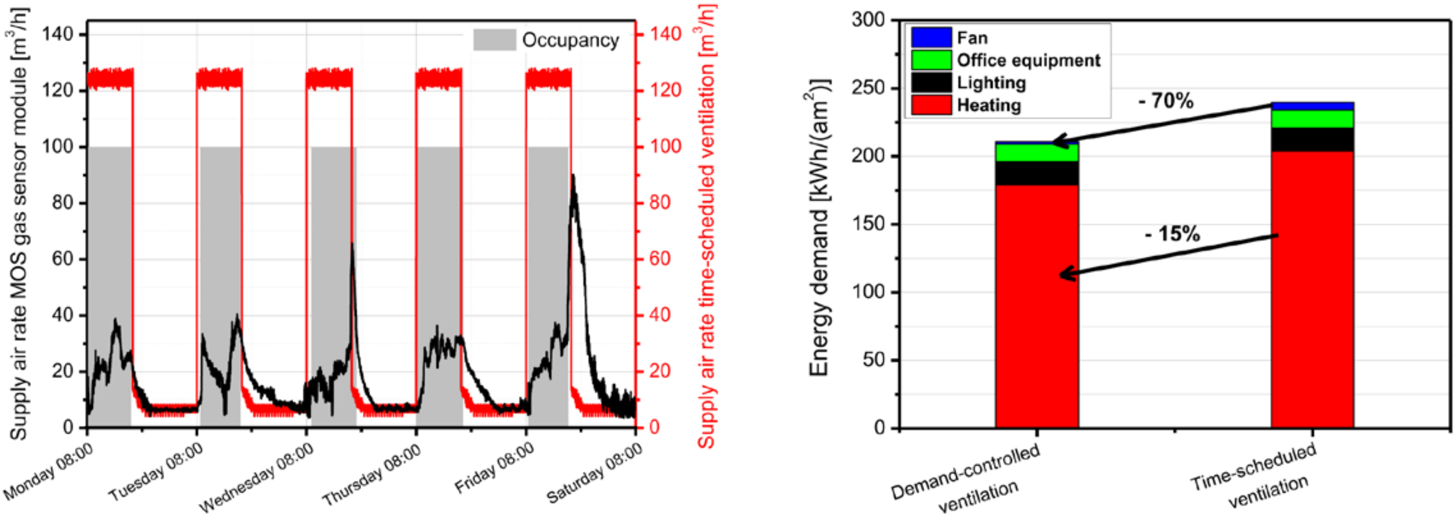


Figure 3. Left: Supply air rate [m³/h] - DCV compared to time-scheduled ventilation.
Right: Energy demand during winter period 2009/2010 for DCV and time-scheduled ventilation.

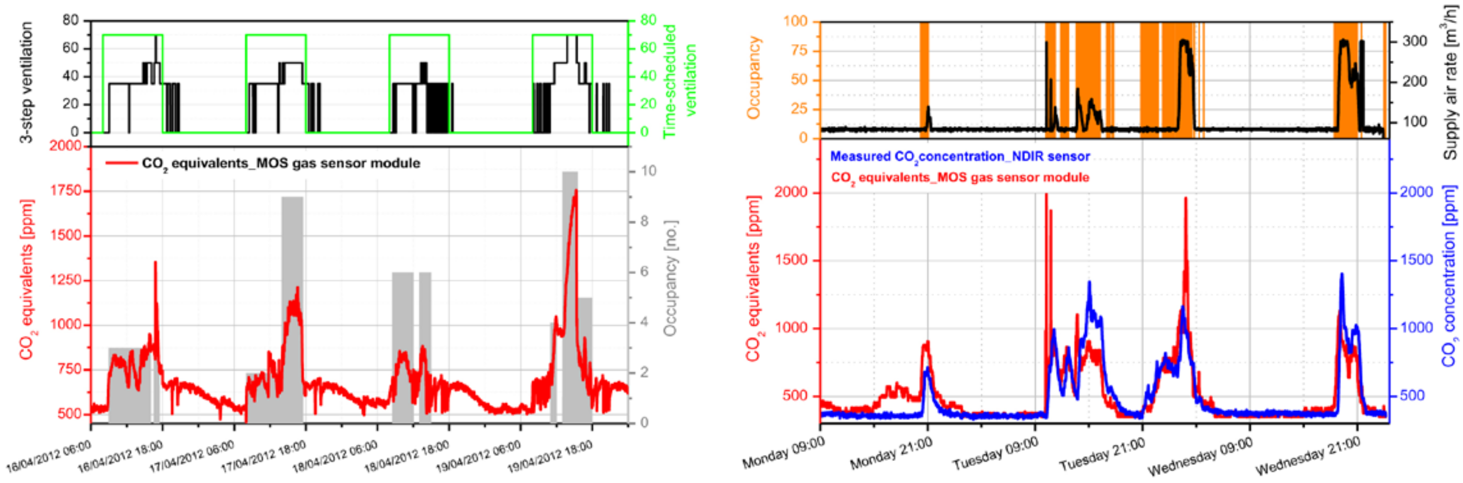


Figure 4. Left: DCV – meeting room. Right: DCV – fitness center.

as shown in **Figure 4**, left hand side. Step 1: 35 l/s, corresponding to sensor output > 700ppm, step 2: 50 l/s, corresponding to sensor output > 900ppm and step 3: 70 l/s, corresponding to sensor output > 1300 ppm.

DCV – fitness center

Installation of the sensor module in an air handling unit in a fitness center resulted in 24% less operating time, which translates to 60% energy cost saving with the overall IAQ rated good.

DCV using iAQ-modules vs. time-scheduled ventilation

The energy findings obtained by the case studies accentuate the need for DCV with AppliedSensor's iAQ-modules regarding actual load conditions in buildings. Human adaption often prevents air quality perception and results in high indoor pollution loads. Time-scheduled ventilation needs air flow rates to be adjusted before start-up depending on the average grade of occupancy or activity in the respective room which often results in a lack of overlap of operation time, ventilation demand, occupancy profiles and indoor pollution load. IAQ control with the developed iAQ-modules however ensures that fresh air is supplied to rooms whenever necessary minimizing the amount of supply air and hence the energy consumption compared to time-scheduled ventilation (**Table 3**).

Table 3. Case studies DCV - Supply air rate reduction.

Case study	Supply air rate reduction
Office	60%
Meeting room	50%
Fitness center	24%

Long term monitoring of residential heat recovery ventilation with ground heat exchange

Introduction: **This article reports the results of a full year monitoring of a zero-energy residential building in Groenlo, the Netherlands. The ventilation system in this building is a demand controlled heat recovery ventilation system in combination with ground heat exchange in the form of an earth pipe. The results of the monitoring show that the ventilation system is highly energy efficient and provides a healthy and comfortable indoor climate.**

Bart Cremers
Consultant Knowledge Centre, Zehnder Group Nederland (PZW)
bart.cremers@zehndergroup.com

The building

The monitored building displayed in **Figure 1** has been built according to the passive house standards. In general terms, the house has a compact, well insulated envelope and south oriented windows with triple glazing. Photovoltaic panels and solar thermal collectors on the roof provide electricity and hot tap water during sunny weather. A heat pump coupled to a vertical bore hole is providing heating and cooling via a floor distribution system. Details of the house can be found in [1] and [2].

Figure 1. The monitored building in Groenlo, The Netherlands.

The ventilation system

A heat recovery unit (ComfoAir 550, abbreviated by HRU) is bringing fresh outdoor air into the building and is removing stale air from the building (see **Figure 2**). The heat from the extract air is recovered and returned back into the fresh air for energy efficient ventilation. The standard ventilation volume is 160 m³/h. In a house with a volume of 840 m³ this corresponds to a ventilation rate of around 0.2 h^{-1}.

The outdoor air is supplied to the individual rooms by 7 individual flexible circular ducts (ComfoTube). Four of them lead to low induction grilles near the floor of the bedrooms (parents, child and guests) and an office room, all situated on the ground floor. The rest leads to the first floor to the living room. Extract air is extracted from the living room, the loft, the bathroom and the toilets via 7 return ducts (ComfoTube). Supply air as well as return air are distributed and collected respectively via sound attenuators (ComfoWell), one in the extract air stream and two in the supply air stream. The kitchen is ventilated by a separate HRU (ComfoAir 350) which is not subject of the monitoring project.

The manual setting of the ventilation volume (standard position 1; 160 m³/h) is increased automatically by a demand control based on 4 individual CO_2 sensors in the living room and the bedrooms (parents, child and guests). If one of the CO_2 levels is above a pre-set threshold level, a signal is brought to the HRU to increase the air volume.

Ground heat is provided by an earth pipe. The earth pipe is 50 m long with a diameter of 200 mm and a mean depth of 2.5 m. It is buried into the earth at a slope to remove any possible condensation in the pipe. An air damper is installed in the fresh air duct upstream of the HRU. The HRU controls the damper to decide whether outdoor air is brought into the building directly from outside (north façade) or via the earth pipe (inlet see foreground in **Figure 1**). **Note**: **Figure 2** shows a slightly different version with 3 parallel and shorter earth pipes without a damper installed.

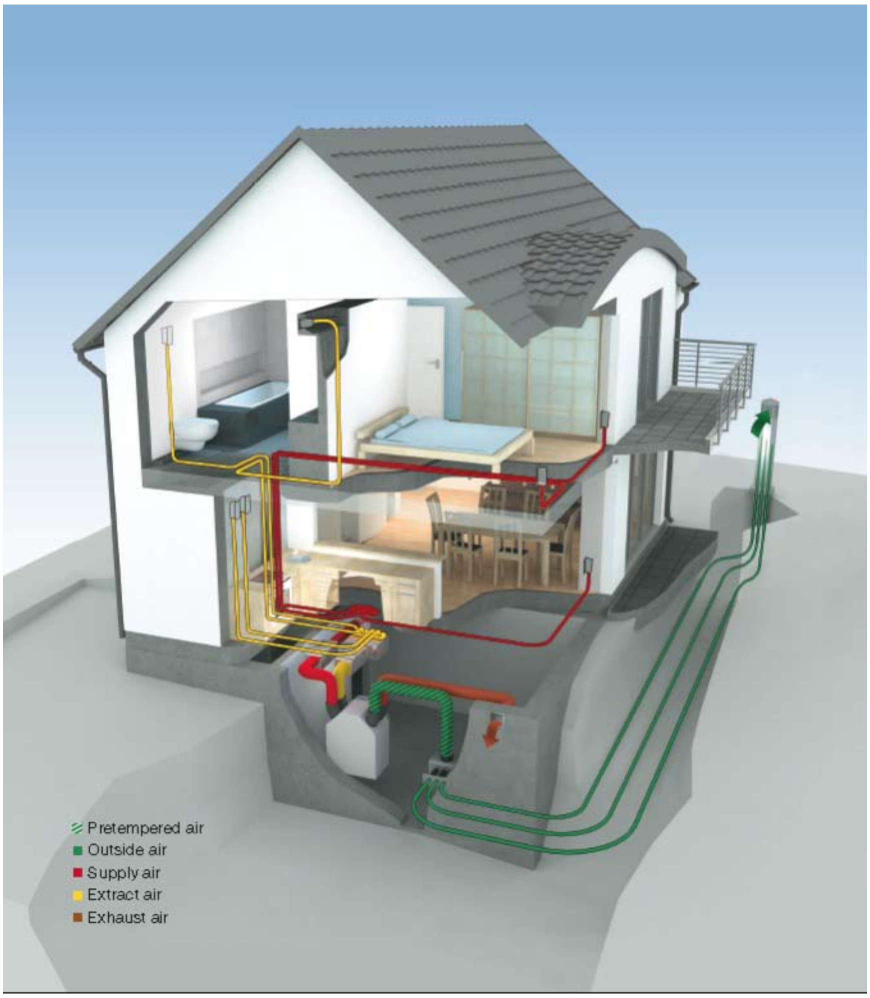


Figure 2. Representation of the ventilation system.

The monitoring

The relevant parameters of the ventilation system have been collected at an interval of 1 minute by a laptop connected to the HRU. The collected data is sent weekly by the resident accompanied by any relevant feedback. The data is transformed into hourly values and analysed in the form of so-called carpet plots, duration graphs, correlation diagrams or bar charts. This report gives the results of a full year starting in February 2011 until February 2012. An intermediate report for a half year period can be found in [3].

Comfortable CO_2 levels

The comfort in the house is assessed by the CO_2 levels in the living room, the master bedroom (2 parents), the child's bedroom and the guest bedroom. The threshold level for the living room was set at 800 ppm and for the bedrooms at 1000 ppm.

As expected, the hourly CO_2 values showed an increased CO_2 level when the rooms were occupied. As an example, **Figure 3** shows the CO_2 levels in the child's bedroom for the period February to May 2011. During the day, CO_2 levels are close to the natural background level of 400 ppm while during the night they were in the range 800 – 1000 ppm. When the CO_2 level exceeded the threshold level of 1000 ppm, the ventilation was increased automatically by the HRU to maintain the CO_2 level within a healthy and comfortable range.

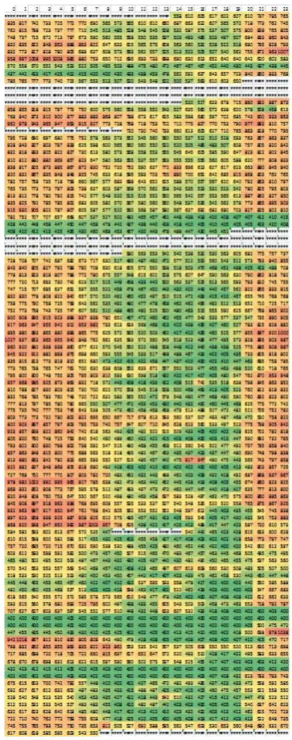


Figure 3. Carpet plot of CO_2 level in the child's bedroom. Rows indicate days from Feb 5th (top row) to May 16th (bottom row). Columns indicate hour of day from 0:00 (left column) to 24:00 (right column). Colours indicate CO_2 level ranging from 400 ppm (green) to 1200 ppm (red), and missing data (white). **Note**: red is still below the Dutch guideline values!

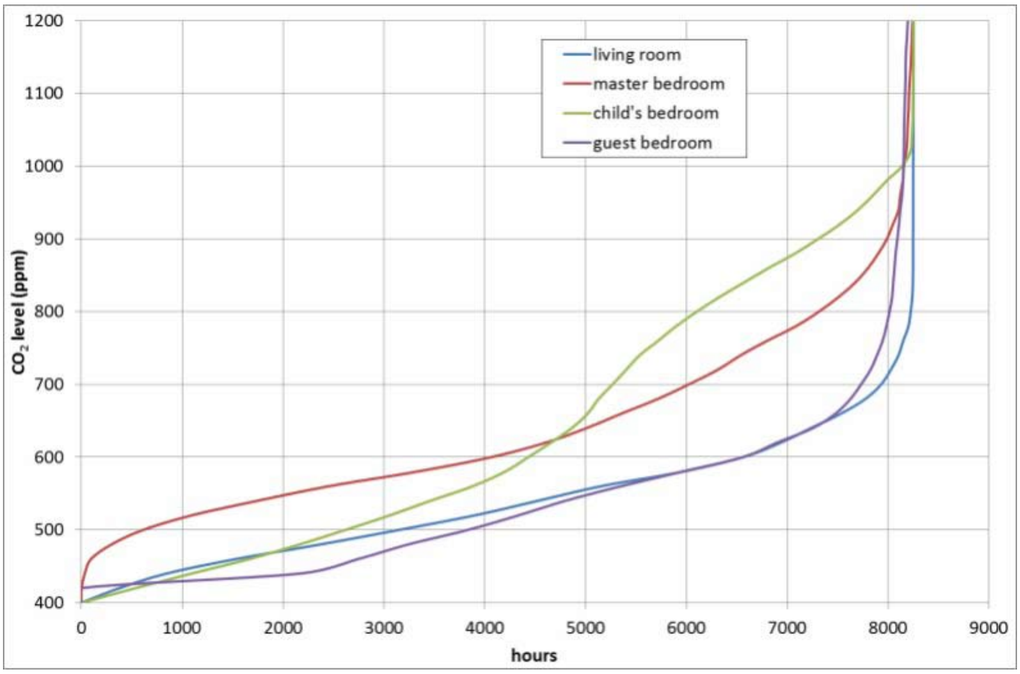


Figure 4. Duration graph of CO_2 levels in living room, master bedroom, child's bedroom and guest bedroom.

From mid-April on, there is a generally lower CO_2 level in all of the rooms resulting from window ventilation used in this period of higher solar irradiation on the south façade.

Another observation is that the CO_2 level during the night was generally higher in the child's bedroom (occupied by one child) than in the master bedroom (occupied by two adults). The reason for this is that the child sleeps with the door closed and the parents sleep with the door open. An open bedroom door results in an exchange of the air in the bedroom (with CO_2 source) with the air in the hallway (without CO_2 source). This pattern was confirmed by CO_2 levels above normal when the master bedroom door was closed occasionally.

The observation of lower CO_2 levels with the door open is confirmed by theoretical calculations. The natural exchange of air by temperature differences between bedroom and hallway can be calculated as 370 m³/h for a door of 1 m wide and 2 m high with a temperature difference of 1°C! This is roughly 6 times more than the amount of fresh air of 58 m³/h provided by the HRU on the maximal level. This means that an open door leads to 6 times faster dilution of CO_2 when compared to a closed door. Note that in case of an open door the CO_2 loaded air is replaced by air from the hallway with unknown air quality, while the HRU ensures the necessary amount of fresh air from outside.

A duration graph of CO_2 levels is given in **Figure 4**. The uncomfortable level of 1200 ppm is exceeded extremely rare (densely occupied bedroom with closed door). Again, one can see higher CO_2 levels in the child's room than the master bed room during the nights. The CO_2 level of 1200 ppm has never been exceeded in the living room and the child's bedroom. In the master bedroom and the guest bedroom, 1200 ppm has been exceeded only 0.1% (8 hrs) and 0.2% (16 hrs) of the time, respectively.

Comfortable temperatures

Throughout the year, the temperature of the earth at 2.5 m depth is much less varying than the outside air temperature. Therefore, the earth can be used for preheating incoming outdoor air in winter and precooling it in summer. In winter, the temperature of the earth is generally higher than the outside air temperature. **Figure 5** shows that the preheated air (at the exit of the earth pipe) is between 8 and 12°C for outside temperatures between -5 and 10°C. In summer, the temperature of the earth is generally lower than the outside air. **Figure 5** shows that the precooled air (at the exit of the earth pipe) is between 12 and 17°C for outside temperatures between 16 and 33°C. For mild outside temperatures between 10 and 16°C the ground heat exchange is switched off by controlling an air valve; outdoor air is taken into the house directly from the north façade (not via earth pipe).

The advantages of the ground heat exchange are the following. In winter, it ensures frost-free operation of the heat exchanger in the HRU, without the need for an electrical anti-freeze heating element. In summer, it decreases the temperature of the outdoor air to a level below the inside temperature, so that free cooling is used for the whole summer period, and not only during cool nights. The extra fan power to draw the air through the earth pipe is negligible (approximately 3 W).

In winter, the (preheated) outdoor air is entering the HRU where it is efficiently heated by the return air in the heat exchanger. **Figure 6** shows that ventilation air is supplied to living room and bedrooms with a comfortable temperature of 18°C in winter even at very low outside temperatures[1]. Without heat recovery, ventilation air would enter the rooms with a temperature equal to outside which would result in uncomfortable draughts.

For outdoor temperatures above 13°C, the heat recovery is switched off when cooling is both requested and available. This occurs when both of the following conditions are true:

- Actual indoor temperature is above the setting of the comfort temperature (here: 21°C)
- Actual pretempered air temperature is lower than actual indoor temperature

The heat recovery is switched off by bypassing the heat exchanger in the HRU. Outdoor air is transported directly (without heat recovery) to the rooms. This results in free cooling of the house as the supply temperature is always below the actual indoor temperature. The monitoring shows that the supply temperature is always below 20°C. As the ventilation air flow rate is not large (160 m³/h), the free cooling cannot be compared with air conditioning equipment, but it raises the comfort and reduces the cooling load of the building.

Energy efficient ventilation

The benefits of heat recovery ventilation with ground heat exchange are expressed in terms of avoided heating and free cooling.

With heat recovery switched on, the avoided heating load (or recovered heat) reflects the fact that, thanks to the HRU, the central heating system does not have to heat cold outdoor air to the desired indoor temperature (see red arrow in **Figure 6**). The exact amount can be calculated using the actual ventilation flow rate and the actual difference between supply air temperature and outdoor air temperature.

1 some hours with supply temperature below 18°C are situations with the central heating switched off during absence.

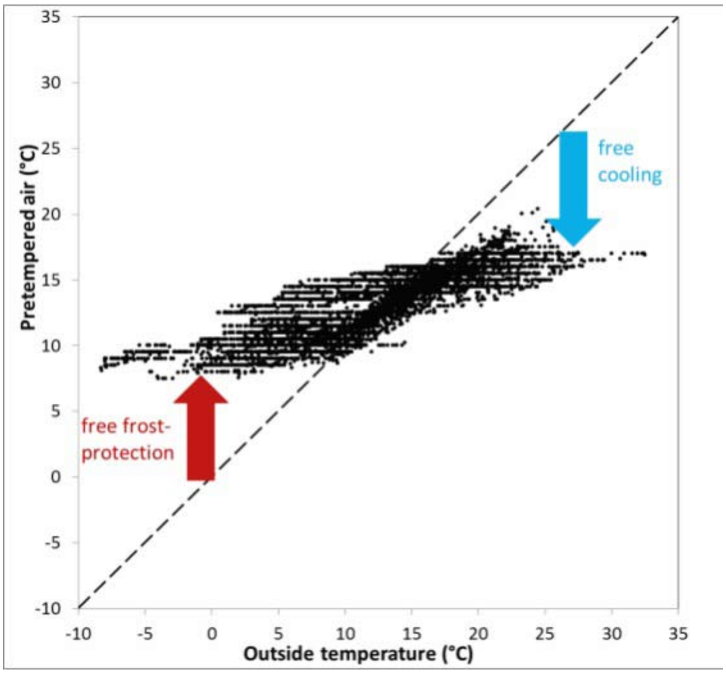


Figure 5. Hourly values of outdoor air entering the house. Ground heat exchange ensures frost protection of the HRU in winter and free cooling for the house in summer.

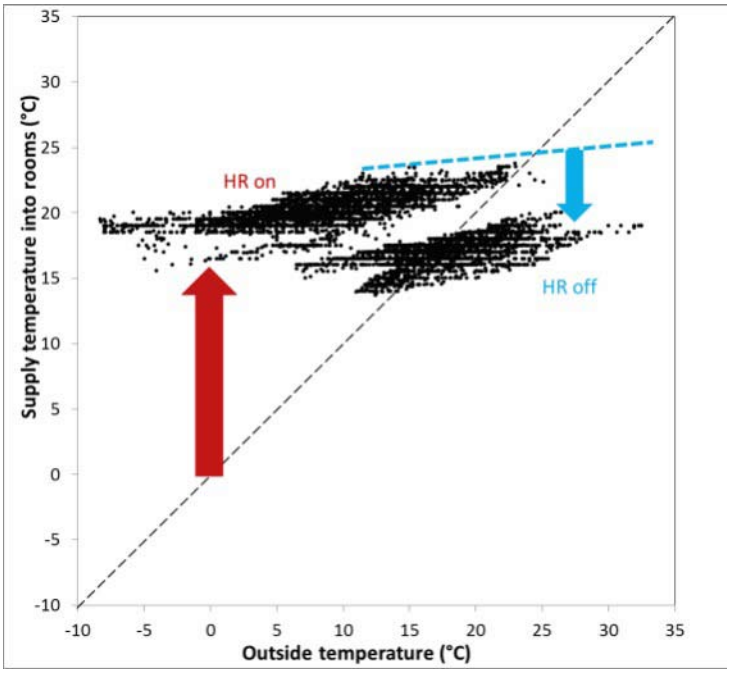


Figure 6. Hourly values of supply air temperature entering the rooms with and without heat recovery (HR on, and HR off). Red arrow indicates avoided heating and blue arrow indicates free cooling compared to indoor temperature.

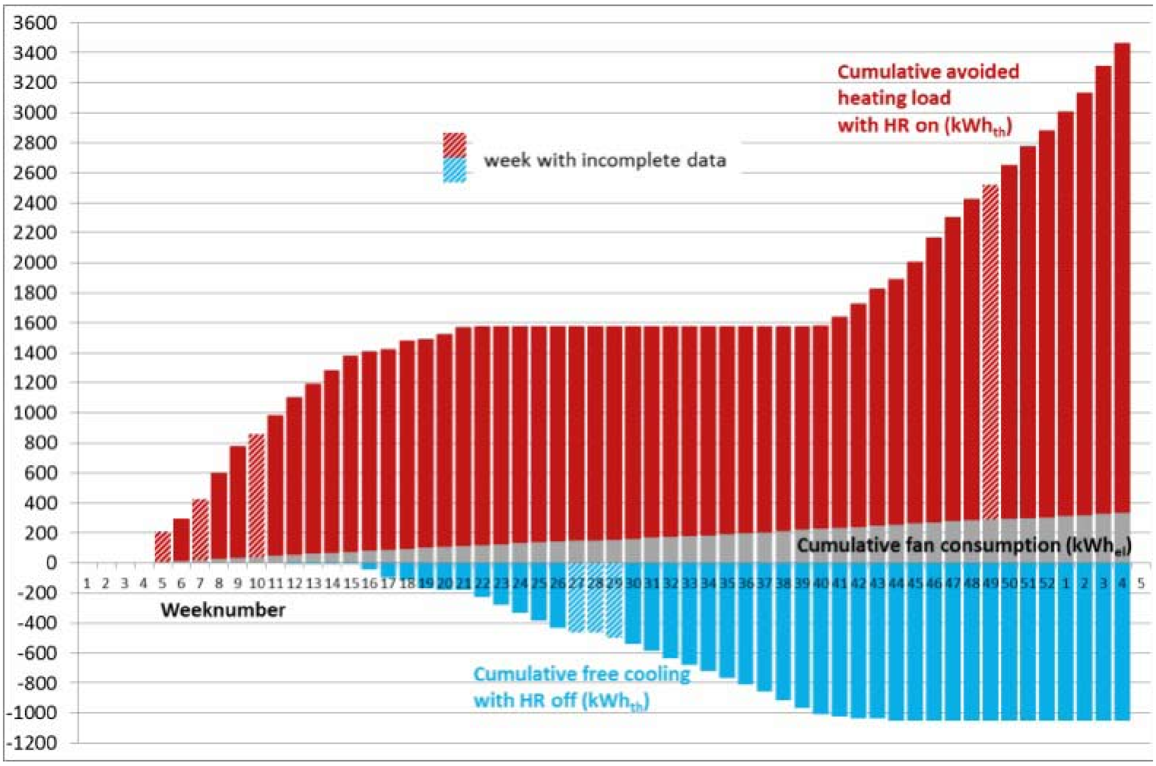


Figure 7. Cumulative avoided heating load (red), cumulative free cooling load (blue) and cumulative fan electricity consumption (grey) from week number 4 in 2011 to week number 4 in 2012.

With heat recovery switched off, the free cooling reflects the fact that the indoor air is cooled by the incoming (lower) supply air temperature (see blue arrow in **Figure 6**). The exact amount can be calculated using the actual ventilation flow rate and the actual difference between indoor air temperature and supply air temperature.

Figure 7 shows cumulative avoided heating load and free cooling per week during the monitoring period. The energy benefits have been obtained at the expense of the electrical consumption of the fans in the HRU, which consume only 33 W at 160 m³/h thanks to the low resistance of the flexible air distribution system.

Table 1 shows a summary of values for the reported period February 2011 until February 2012. The seasonal performance factor SPF for avoided heating (or free cooling) is given by the ratio between avoided heating load (or free cooling load) and the electricity consumption of the fans during hours when the bypass was closed (or open). The observed SPF for avoided heating corresponds reasonably well with an SPF of 22 for the expected gain of a heat recovery system using comparable climate data of Milan, Italy from [4].

Table 1. Annual energy benefit of heat recovery ventilation and seasonal performance factors.

	Full year	Electrical consumption of fans during season	Seasonal Performance Factor SPF
Avoided heating load	3465 kWh	199 kWh	17
Free cooling load	1052 kWh	137 kWh	8

Thermal efficiency of heat recovery in practice

The thermal efficiency is defined as the ratio between outdoor air temperature increase and maximal temperature increase $(T_{supply\ air}-T_{fresh\ air})/(T_{return\ air}-T_{fresh\ air})$. When ground heat exchange is used, the outdoor air temperature in this formula is the preheated or precooled outdoor air temperature.

The thermal efficiency of an HRU is dependent on a lot of variables, among which ventilation flow rate and mass balance between supply air and extract air are dominant. **Figure 8** shows practical efficiency as a function of fan percentage. The HRU is most frequently in position 1 (fan percentage 35%). Fan positions 2, 3 and absent can also be discerned. Intermediate fan

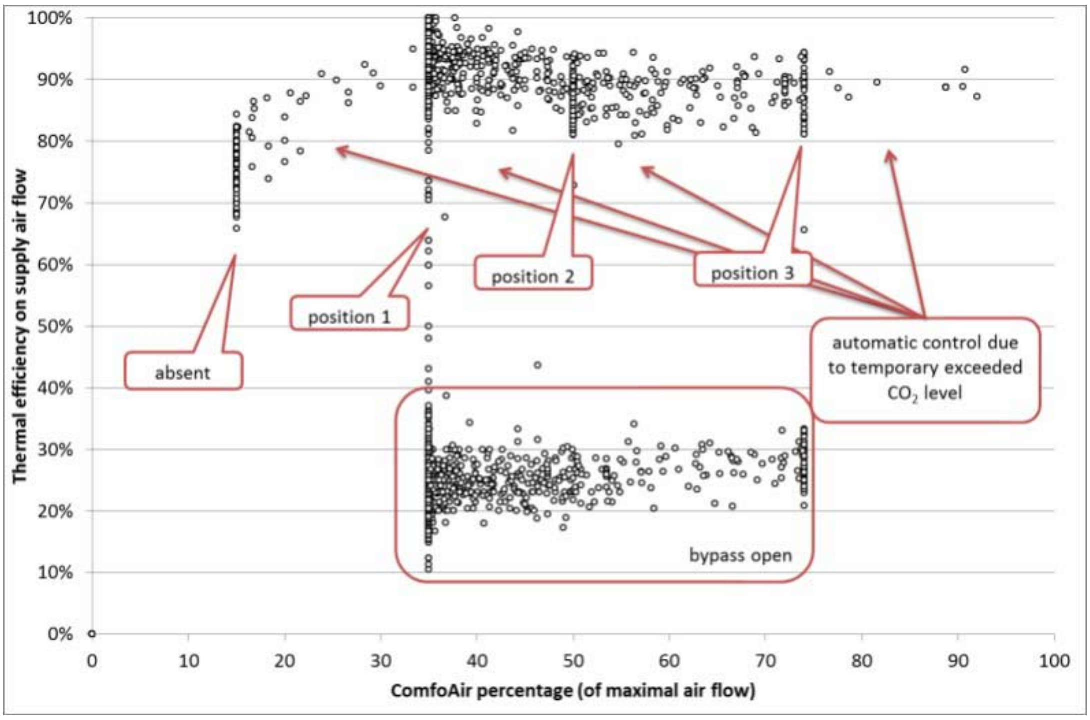


Figure 8. Thermal efficiency of HRU as a function of fan percentage (of maximal rotational speed).

percentages occur when the CO_2 demand control increases fan percentage gradually.

With the bypass open (heat recovery switched off), the average undesired thermal efficiency is still 24%. Optimally, this efficiency would be 0%, but the fans add a small amount of heat (approximately 2°C) to the outdoor air, in spite of the use of efficient EC fans. If AC fans had been used, the thermal efficiency would be even higher.

With the bypass closed (heat recovery switched on), the optimal efficiency is obtained for the most frequently used fan position 1 (160 m³/h). For the position 'absent' efficiency is decreasing, probably coming from imbalance in mass flows for very low flow regions. For higher fan speeds, the thermal efficiency is slowly decreasing because air is moving fast in the heat exchanger so that the limited exchanger surface becomes noticeable.

The observed average thermal efficiency with bypass closed is as high as 91%. This is a high number considering the fact that the supply air flow and the extract air flow are not perfectly balanced. The resident of the house has commissioned the HRU with a lower extract air flow than supply air flow rate. Detailed flow rate measurements revealed a 6% imbalance in volume flows. Mathematically, one can correct for this imbalance to obtain 89%/(100% - 6%) = 97%. This means that, if the HRU system was commissioned in balanced flow, a thermal efficiency of 95% would be obtained, which corresponds perfectly with the thermal efficiency as measured in laboratory.

Conclusion

The monitoring of a demand controlled heat recovery ventilation system with ground heat exchange in a zero-energy building in Groenlo, The Netherlands, revealed interesting practical insights. A healthy indoor climate can be obtained with a high comfort in terms of CO_2 levels and supply air temperatures. The energy efficient behaviour is proven by the avoided heating load of 3465 kWh and free cooling of 1052 kWh during a full year. The observed seasonal performance factor SPF is 17 for the avoided heating and 8 for the free cooling.

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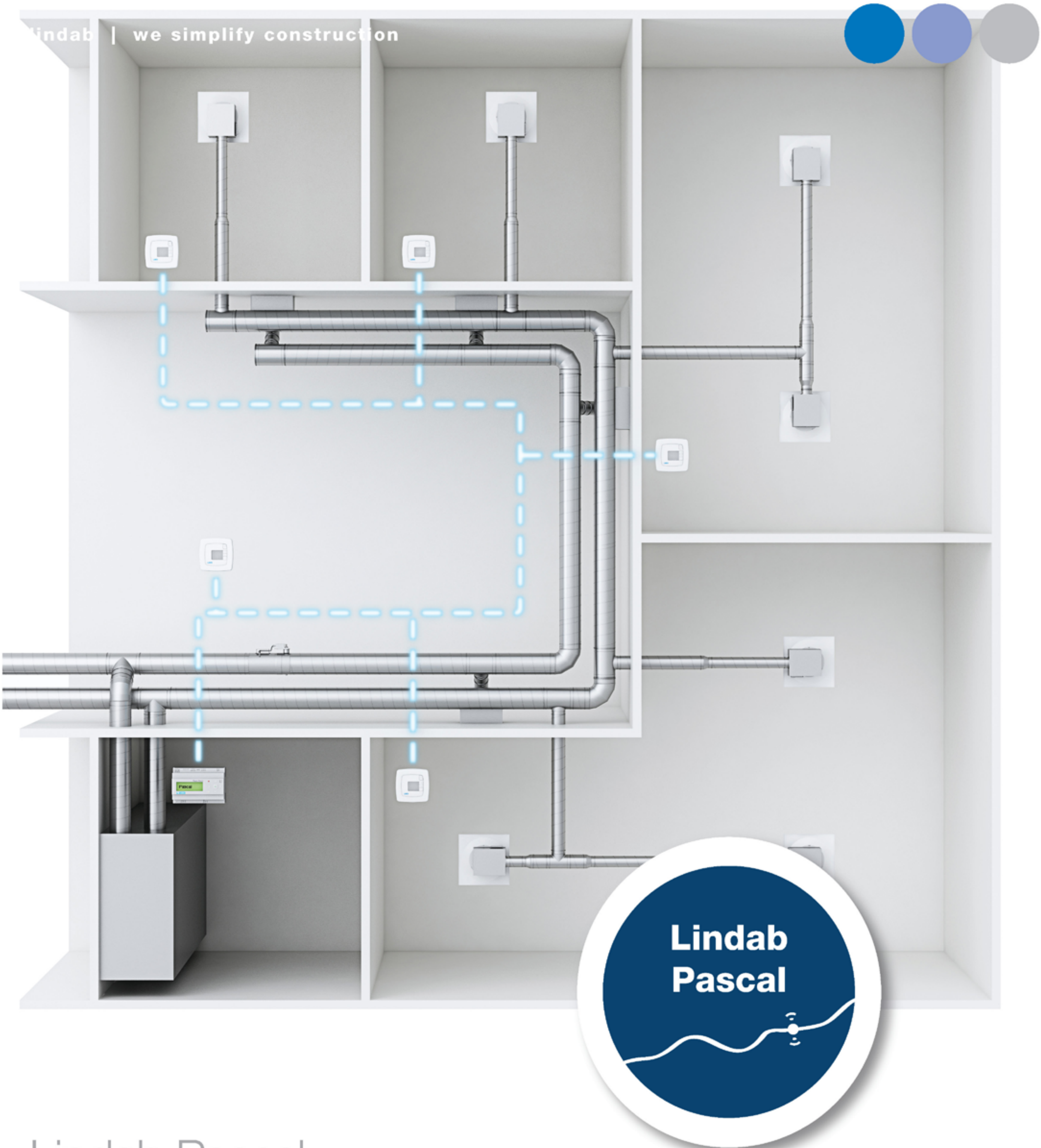

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The contents of the Energy efficiency directive agreed on Jun 14th

A provisional deal on the proposed new EU energy efficiency directive was struck by MEPs and Council negotiators of the European parliament and the Council on Thursday 14 June. This directive would require EU Member States to save energy in specific ways, e.g. by renovating buildings and stipulating the size of energy savings to be delivered by utilities. The EU has set itself the target of improving energy efficiency by 20% by 2020 (from 2005 levels), but the European Commission estimates that the EU will achieve only half that improvement unless it takes specific measures. The proposed directive establishes a common framework for these measures. EU Member States would have to set themselves national energy efficiency targets, and by June 2014, the Commission would have to assess the progress achieved to date. The proposed directive would replace two existing directives - the Energy Savings Directive (ESD), and the Cogeneration Directive. It aims to fill gaps where measures are lacking, improve the effectiveness of existing ones, and in doing so, to provide a boost to the economy. The European Parliament believes that energy efficiency can help drive the EU by reducing dependence on imports, creating jobs, freeing up financial resources, enhancing industrial competitiveness, and reducing greenhouse gas emissions.

The following summarizes the measures that would be required by the directive. In the negotiations several exemptions were added into the final text to be able to reach the consensus. These exemptions weaken the impact of the directive.

Renovating public buildings

The directive would require EU Member States to renovate 3% of the total floor area of "heated and/or cooled buildings owned and occupied by their central government". This would apply to buildings with a "total useful floor area" more than 500 m², and as from July 2015, of more than 250 m². However, Member States would also be able to use alternative means to achieve equivalent energy savings, such as thorough renovations.

Long-term strategy for national building stocks

In order to capture growth and job opportunities in the skilled trades and construction sectors, as well as in the production of construction products and professional activities such as architecture, consultancy and engineering, each Member State would need to establish a long-term national strategy (by January 2015), to "mobilise investment" in the national stock of residential and commercial buildings, both public and private.

This strategy would have to include:

(i) an overview of the national building stock based, as appropriate, on statistical sampling,
(ii) an identification of cost-effective approaches to renovation, relevant to the building type and climatic zone,
(iii) policies to stimulate cost-effective "deep" renovations of buildings, including those done in stages,
(iv) forward-looking guidance for investment decisions by individuals, the construction industry and financial institutions, and
(v) an indicative estimate of expected energy savings.

The strategy would have to be submitted to the Commission, published by 1 January 2015 and updated as appropriate thereafter.

Targets for energy savings

Each Member State shall set up an energy efficiency obligation scheme. **That scheme shall ensure that obligated energy distributors and/or retail energy sales companies operating in each Member State's territory achieve a cumulative end-use energy savings target by 31 December 2020. That target shall be *at least* equivalent to achieving new savings each year from 1 January 2014 to 31 December 2020 of 1.5% of the annual energy sales to final customers.**

Public procurement

Member States would be required to ensure that "central governments" purchase only goods, services and buildings with high energy-efficiency performance, insofar this is consistent with cost-effectiveness, economic feasibility, wider sustainability, technical suitability, and sufficient competition

Energy audits

All large enterprises would be required to undergo energy audits. These would need to start within three years of the directive's entry into force and be carried out every four years by qualified and accredited experts. Households and small and medium-sized enterprises would be excluded from this requirement.

Exemptions

Large companies which are already implementing an energy or environmental management system that is certified by an independent body according to the relevant European or international standards would be exempted from this requirement, provided the management system includes an energy audit.

Smart metering and new buildings

EU countries would need to ensure that, in so far as it is technically possible and financially reasonable, final customers for electricity, natural gas, district heating, district cooling and domestic hot water are provided with competitively-priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use.

New buildings

When a new connection is made in a new building or a building undergoes major renovations, as set out in the EPBD Directive 2010/31/EU, such competitively-priced individual meters would always have to be provided.

Individual consumption meters in multi-apartment buildings

In multi-apartment and multi-purpose buildings with a central heating/cooling source or supplied from a district heating network or from a central source serving multiple buildings, individual consumption meters would have to be installed by 1 January 2017 to measure the consumption of heat or cooling or hot water for each unit where technically feasible and cost efficient. Where the use of individual meters is not technically feasible or not cost-efficient, to measure heating, individual heat cost allocators would have to be used to measure heat consumption at each radiator, unless it is shown by the Member State in question that the installation of such heat cost allocators would not be cost efficient. In such cases, alternative cost-efficient methods of heat consumption measurement could be considered.

Billing and consumer information

Member States would be required to ensure, by 1 January 2015, that billing information is accurate and based on actual consumption, in order to enable final customers to regulate their own energy consumption. Billing would take place on the basis of actual consumption at least twice a year, or quarterly, upon request. Where billing is done electronically and without request, it would be quarterly. When sending customers contracts, contract changes or bills, including through those sent through websites addressing customers individually, energy distributors, distribution system operators and retail energy sales companies would have to inform them, in a clear and understandable manner, of the contact details of independent consumer advice centres, energy agencies or similar institutions, including their internet addresses, where they can obtain advice on available energy efficiency measures, benchmark profiles for their energy consumption and technical specifications of energy-using appliances that could help to reduce energy consumption.

Assessing scope for high-efficiency district heating and cooling

Member States would need to carry out and notify to the Commission by December 2015 a "comprehensive assessment" of the scope for applying high-efficiency cogeneration and efficient district heating and cooling. For the purposes of this assessment, Member States would need to carry out a cost-benefit analysis - a proposal introduced by MEPs - covering their territory based on climate conditions, economic feasibility and technical suitability.

Cost-benefit analysis

The cost-benefit analysis would have to be capable of facilitating the identification of the most resource and cost-efficient ways to meet heating and cooling requirements. Where the assessments identify potential for applying high-efficiency cogeneration and/or efficient district heating and cooling whose benefits exceed the costs, Member States would have to take appropriate measures for efficient district heating and cooling infrastructure to be developed and/or to accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources.

Risk of carbon leakage and Emissions Trading System

The European Commission would monitor the directive's impact on industry sectors, and particularly those exposed to a significant risk of carbon leakage, so as to ensure that the directive's provisions promote, rather than impede, the development of these sectors. The draft directive includes a written statement by the Commission referring to Phase 3 (2013-2020) of the EU Emissions Trading System (ETS - which is to deliver two-thirds of the 20% emissions reduction target

Next steps

The provisionally agreed text will be put to an Energy Committee vote, probably in July, and then a plenary one in September (provisional timetable). **OS**

EU Ecolabel and Green Public Procurement for Office Buildings

European Commission DG Environment with help of the Joint Research Centre, Seville, is developing an EU Ecolabel that awards the best environmental performance buildings and GPP (Green Public Procurement) criteria to promote an environmentally-friendlier public consumption. The EU Ecolabel for buildings will allow consumers to identify the officially kinder environmental products easily and manufacturers to show and communicate to their customers that their products respect the environment. In addition, the EU Ecolabel will not create barriers to trade, just on the contrary, it can give a competitive advantage.

This study is being carried out by the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS). The work is being developed for the European Commission's Directorate General for the Environment.

The process can be followed through the project website (http://susproc.jrc.ec.europa.eu/buildings/whatsnew.html) . Stakeholder involvement is a crucial part of this study. By_registering (http://susproc.jrc.ec.europa.eu/buildings/register.cfm) as a stakeholder, you can stay informed of latest additions to this site and engage in the consultation.

The EU Ecolabel and GGP criteria for Buildings will consist on environmental criteria. The criteria will be based on scientific assessment studies of the environmental impacts of the building for each part of its life cycle (e.g. LCA studies) and consider different environmental aspects such as air quality, water quality, soil protection, waste reduction, energy savings, natural resource management, GWP, ozone layer protection, environmental safety, noise and biodiversity. Moreover, the EU Ecolabel and GPP criteria should be agreed at European level, following wide consultation with experts. An updated summary of the discussion held during the 2nd AHWG for EU Ecolabel criteria for Office building and the summary of the 2nd meeting for the development of GPP criteria for this product group that took place on Wednesday 18th January 2012 in Brussels were recently made available at the project website.

Key Environmental Impacts Included in the Criteria

The key environmental impacts from office buildings are strongly associated with the consumption of energy in the use phase. Further, significant environmental impacts are associated with: **a)** energy consumption in the production and construction phase, **b)** use of hazardous constituents and materials that coming from no sustainable sources, **c)** consumption of water and generation of waste (along all the phases of the office building). Other impacts are related to the indoor air quality and the well-being/comfort of the employees. **OS**

European Commission, Joint Research Centre, Institute for Prospective Technological Studies.
C/ Inca Garcilaso 3, 41092 Seville, SPAIN;
Tel.: +34 954 48 8318, Fax: +34 954 48 8300. © 2010

More information: alicia.boyano@ec.europa.eu and http://susproc.jrc.ec.europa.eu/buildings/stakeholders.html

The Commission prepares the Intelligent Energy-Europe programme (IEE III) for 2014-2020

Intelligent Energy – Europe II (IEE II) is one of the three pillars of the Competitiveness and Innovation Framework Programme (CIP) and the main EU instrument for non-technological support in the field of energy. Its objective is to contribute to removal of market barriers that hamper the efficient use of energy and increased use of renewable energy sources.

As the **Intelligent Energy-Europe II (IEE II) programme (2007–2013)** draws to a close, options for following it up with a successor need to be considered.

The programme is playing a key role in EU efforts to meet the EU 2020 targets. It has enabled more efficient implementation of a number of Directives and other policy initiatives such as the **Energy Performance of Buildings Directive,** the **Eco-design Directive,** the **Energy Labelling Directive** and **Renewable Energy Directive.** With the new **Energy Efficiency Directive** as a regulatory backbone, the Programme will in its last year (2013) start to create the institutional and knowledge base for closing the energy efficiency gap.

With a budget of €730 million during the period 2007–2013, IEE II has supported **more than 300 actions** in all relevant sectors of the EU economy, striving to improve market conditions, to develop the skills of professionals, to define and implement legislation, to raise awareness of successful solutions through knowledge-sharing and by promoting best practices, and stimulating investments in sustainable energy. Most of the EU projects REHVA has participated have been funded from the IEE-II programme, see http://www.rehva.eu/en/european-projects.

In the Commission's proposal for the next Multiannual Financial Framework (2014–2020), it has been proposed that the successor to IEE II (IEE III), will continue in the under the Energy Challenge of the future EU programme for Research and Innovation ´Horizon 2020´. This public consultation will provide an important contribution for shaping IEE III in Horizon 2020.

The Commission proposes that IEE III should address the following three main areas:

a) Policy implementation support, focusing on technical support for specific activities to promote efficient development and implementation of policies and legislation at EU, national and local level, on energy efficiency and renewable energy sources;
b) Capacity-building, addressing public acceptance, knowledge transfer and skills improvement; and
c) Financing to mobilise investments and make energy efficiency and distributed renewable energy projects bankable, via provision of project development assistance, 'business' and 'investments' capacity building and dialogue with project promoters, policy makers and investors/financiers. Specific attention will be given to the retail financial institutions and market-based financing mechanisms.

The Commission has opened the public consultation process for the IEE III programme. The Commission invites stakeholder to reply to this public consultation by answering the IPM on-line questionnaire **by 5 September 2012 at the latest**.

Received contributions will be published on the Internet. It is important to read the specific privacy statement attached to this consultation for information on how your personal data and contribution will be dealt with. Non-registered organization responses will be published separately.

OS

For more information on the Commission Public Consultation Paper and Online Questionnaire please visit http://ec.europa.eu/energy/efficiency/consultations/iee3_in_horizon_2020_en.htm

CHILLVENTA 2012

International Trade Fair for Refrigeration, Air Conditioning, Ventilation and Heat Pumps

The next Chillventa takes place in Nuremberg, Germany from Tuesday to Thursday, 9–11 October 2012.

Chillventa 2012, the exhibition highlight for the refrigeration, air-conditioning, ventilation and heat pump sectors, is approaching rapidly. The preparations for the next Chillventa, which offers three great days for intensive talks with experts, now with new opening days from Tuesday to Thursday, are already in full swing.

Cleanroom Village creates synergies

Chillventa 2012 presents the Cleanroom Village once again. This special feature in hall 1 offers designers, plant assemblers and operators of clean and ultra-clean rooms an internationally orientated exhibition forum for information on air-conditioning and ventilation. "Cleanroom technology is an ideal enhancement for Chillventa, as shown by the successful premiere of the Cleanroom Village at Chillventa 2010. The Cleanroom Village creates synergies that benefit both exhibitors and visitors," explains Gabriele Hannwacker, Exhibition Director at NürnbergMesse. The exhibitors in the Cleanroom Village show innovative technologies and concepts for the design, construction and operation of cleanrooms in industry and research.

Energy efficiency a major factor

Chillventa 2012 focuses on energy efficiency and sustainability. "Politics and industry throughout the world are pursuing ambitious plans for reducing CO_2 and greenhouse gas emissions. The manufacturers have recognized the signs of the times and present optimized system solutions and components at Chillventa. They not only spare the environment, but also set standards in terms of cost-effectiveness," says Gabriele Hannwacker. The energy-saving products on display at Chillventa cover the whole range from A to Z, with equipment such as axial ventilators, two-stage compressors etc.

For more information visit Chillventa 2012 can be found at: www.chillventa.de/en/ **CD**

7th International HVAC Cold Climate Conference

12-14 November 2012, Calgary, Alberta, Canada.

ASHRAE along with industry colleagues from around the world of HVAC, architecture, interior design and building construction will host the 7th International HVAC Cold Climate Conference, November 12-14, 2012 in Calgary, Alberta, Canada.

The principal objective of Cold Climate HVAC 2012 is to provide key elements of a strategy by which scientists, designers, engineers, manufacturers and other decision makers in cold climate regions can achieve good indoor environmental quality (IEQ), with a minimum use of resources and energy.

For more information please visit the conference website at http://ashraem.confex.com/ashraem/icc12/cfp.cgi

FinnBUILD

11 October 2012

FinnBuild presents the best expertise, products, services and solutions for construction in its 20th fair. FinnBuild stays up-to-date and renews itself along with the industry. The largest and most prominent event in the construction industry in Finland attracts visitors who want to keep themselves at the forefront professionally.

In addition, the Exhibition & Convention Centre will host five other professional events simultaneously with the FinnBuild fair.

Technical infrastructure will have its first dedicated professional exhibition in autumn 2012. **InfraExpo** (http://web.finnexpo.fi/Sites1/InfraExpo/en/Pages/default.aspx) presents road and rail networks, energy supply networks, water technology, telecommunications networks, bridges, tunnels, harbours, airports and current electronic software and services and the networks combining these.

The **Environment and Municipal Engineering, Water and Wastewater, and Waste and Recycling** (http://web.finnexpo.fi/Sites3/YT2012/en/Pages/default.aspx) events are aimed at professionals who are responsible for the procurement of environmental, municipal engineering and waste technologies and services, as well as energy and water management.

For more information please visit www.finnbuild.fi

REHVA and FINVAC seminar at FinnBuild 2012

In the Helsinki Exhibition & Convention Centre, FINVAC and REHVA will host a seminar on October 11th, 2012. The topic of the seminar is **Implementation EU energy efficiency policy in Finland**. For more information about this seminar, please visit www.rehva.eu or contact info@rehva.eu.

A SEMINAR AT EUSEW ORGANISED BY EPEE, EUROVENT AND REHVA

Energy Efficient Buildings – Healthy people

The participants at the seminar represented wide range of expertise from health sciences to industry. The consensus of the seminar was that a common declaration on the importance of indoor environmental quality is needed.

"Energy efficient buildings – healthy people" was the title of an event organised by the heating, cooling and ventilation associations EPEE, Eurovent and REHVA during the EU Sustainable Energy Week (EUSEW). More than 70 experts from a range of backgrounds attended the seminar, dedicated to the importance of indoor air quality.

Recently, the EU has strongly focused on energy efficient buildings - and has thus not granted less attention to indoor air quality. However, this topic plays a major role: the majority of our lifetime is spent indoors and the indoor environment has not only a major impact on our health but also on our productivity at work. Studies also show that the performance of students in school increases significantly, up to 15%, when ventilation is improved.

The speakers of the seminar represented patients, science and industry: Roberta Salvi, European Federation and Allergy and Airways diseases, EFA; Ronald Dahl, professor for respiratory medicine at Aarhus University in Denmark, Professor Bjarne Olesen, Danish Technical University; Michel van Roozendaal from EPEE and Jan Andersson from Camfil Farr. They took also part in a lively debate with participants, addressing key points on how to improve indoor air quality. Among them: education and awareness raising in IEQ issues; setting and following standards, integrating indoor environmental issues in energy inspections and certificates; improvement of communication between experts and policy makers; including the indoor environmental issues in the EU Environmental action programme and EU R&D programmes.

As a key outcome of the debate and in view of the 2013 "Year of the Air", organisers of the seminar with participants decided to develop a green paper dedicated to the improvement of indoor air quality. Andrea Voigt, EPEE Director General summarises: "With the Energy Efficiency Directive, Ecodesign and the recast EPBD, the way has been paved for the improvement of energy efficiency. We now need the same kind of strong signals in terms of indoor air quality and look forward to supporting policymakers in finding the best solutions to achieve this." OS

Panellists from left: Prof Ronald Dahl, Mr Jan Andesson, Prof Bjarne Olesen.

Panellists Mr Michel van Roozendaal and Ms Roberta Savli focusing on the presentation of health effect of indoor environment by Prof Ronald Dahl.

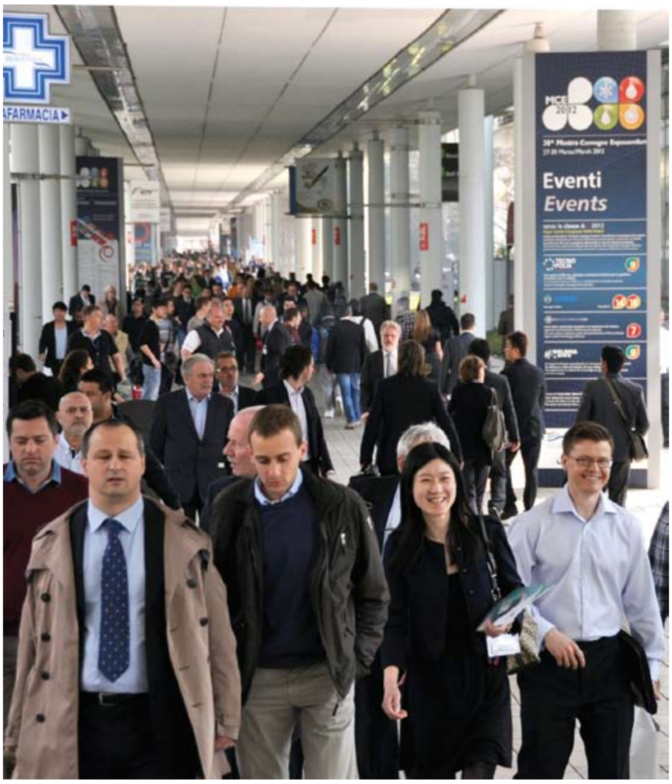
EPEE **European Partnership for Energy and the Environment** represents a group of HVAC&R companies in the construction sector. Its mission is to promote a better understanding of the HVAC&R sector in the EU and to contribute to the development of effective European policies in order to achieve a long-term sustainability agenda.

EUROVENT **European Committee of Air Handling and Refrigeration** is the representative of the European refrigeration, air-conditioning, air handling, heating and ventilation industry and representing trade associations from European and non-European countries.

REHVA **Federation of European Heating, Ventilation and Air-conditioning Associations** is the leading professional organization in Europe, dedicated to the improvement of health, comfort and energy efficiency in all buildings and communities. Its 26 national members represent over 100 000 HVAC&R professionals in Europe.

Succesful Mostra Convegno exhibition in Milan

The four-day exhibition recorded over 155,000 trade and professional visitors with a 4% rise in foreign participant numbers.



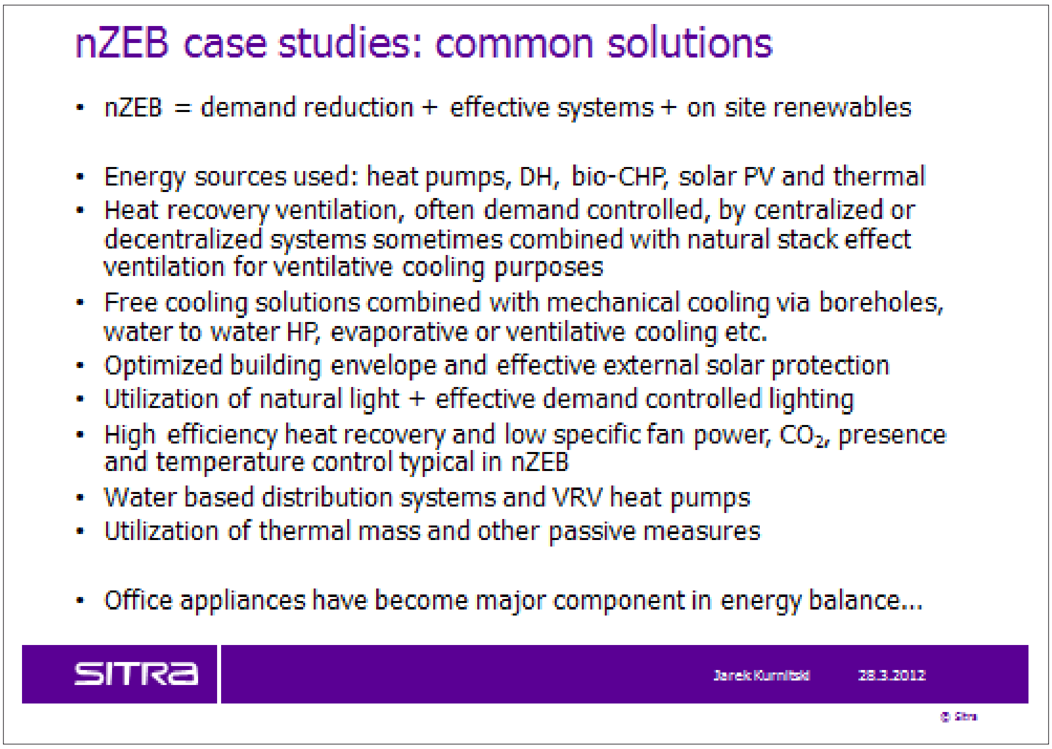
The 2012 edition MCE – Mostra Convegno Expocomfort staged at Fieramilano from 27th through 30th March, has registered the participation of more than **155,000 trade and professional visitors**, with **a 4% increase** in international visitor numbers confirming its world leadership in diverse industry sectors including residential and industrial installations, air-conditioning, and renewable energy.

More than **2100** exhibitors, including over **900 foreign exhibiting companies from 58 countries** participated in this edition. An exhaustive overview of the best-in-class products and ground-breaking solutions available on the market today in terms of technological innovation aimed to highlight energy efficiency and saving. The level of excellence was appreciated in particular by professionals who filled the aisles of MCE 2012 (occupying a total gross exhibition area of **325,000 square meters**), always on the hunt of new products and much more. The success of MCE depended on its proven ability to combine a top-level showcase of solutions with a full conference programme. As a matter of fact, a broad audience of trade visitors attended conferences, events and initiatives providing training and professional development opportunities.

"Over the years MCE", explained *Massimiliano Pierini*, *Business Unit Director Reed Exhibitions Italia*, "has reached its goal becoming an international point of reference for exhibitors and visitors, to not only bring together supply and demand, but to create a unique opportunity for in-depth analysis, technical and cultural debate and discussion.

"Zero Energy 2020: towards building technology integration" has been the common thread running through MCE 2012, aimed to highlight 27 macro sectors, the excellence in manufacturing sector, ranging from air-conditioning to refrigeration, heating, implements and tools, sanitary technology, taps and fittings and the bathroom, solar thermal and cogeneration, biomasses and photovoltaic. An atmosphere of great dynamism of the market pervaded the exhibition creating the right conditions to capture international growth.

REHVA organised in collaboration with AiCARR a Seminar focusing on Zero Energy Buildings during the exhibition. The seminar was very well attended. More than 200 experts enjoyed the high quality presentations



Jarek Kurnitski summarized earlier in the REHVA journal the common design solutions of nearly zero energy buildings he presented in the REHVA - AICARR seminar. The whole presentation as well as all other presentations in the seminar are available at http://www.rehva.eu/en/537.rehva-and-aicarr-seminar-at-mce-hvac-in-zero-energy-buildings-28-03-2012.

of REHVA experts. One of the highlights of the seminar was the summary of design features and performance of Nearly Net Zero Energy Buildings in Finland, France, the Netherlands and Switzerland. The common design features of high performance buildings are summarizes in the figure below from Prof Jarek Kurnitski´s presentation. All the presentations of the AiCARR - REHVA seminar are available at www.rehva.eu.

The organization has already started working on the next edition scheduled for 18 - 21 March 2014, always at Fieramilano. **OS, CD**

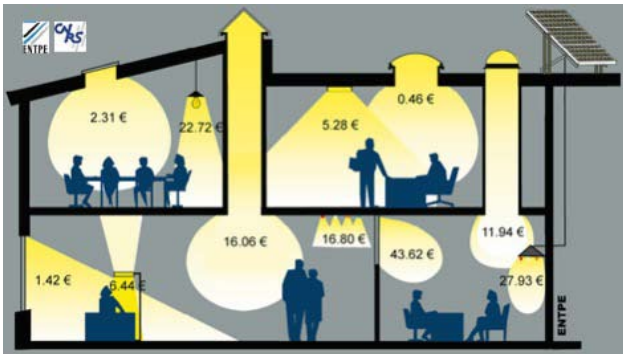
Light+Building Exhibition in Frankfurt attracted 196,000 visitors

Some 196,000 visitors made their way to Frankfurt for Light+Building 2012, The World's Biggest Trade Fair for Lighting and Building Services Technology, which closed its doors on 20 April. This is an increase of around 7% compared to the last edition. At the fully booked up Frankfurt Fair and Exhibition Centre, 2,352 manufacturers from 50 countries presented their latest products and trends for the fields of lighting, electrical engineering, home and building automation and software for the construction industry. The increase in the number of visitors comes equally from home and abroad. The proportion of international visitors rose again and has now reached 44%. In other words, almost one in two visitors came from outside Germany.

"Light+Building is the world's biggest trade fair for energy efficiency. Accounting for 40% of the total, buildings are the world's biggest consumer of energy and, therefore, play an important role for smart grids and decentralised energy supply. The very good result shows the extent of worldwide demand for environmentally friendly light and building-services solutions – and that Light+Building is the foremost meeting place for the industry and decision makers. As we learnt in many discussions during the fair, the results exceeded the sector's expectations", said Wolfgang Marzin, President and Chief Executive Officer (CEO) of Messe Frankfurt.

The economic outlook in the sector is seen in a very positive light. 91% of visitors and 83% of exhibitors are satisfied with the economic situation. The visitor structure remained more or less unchanged with the main groups coming from the installation trade, industry and trade, as well as architects, light planners and engineers.

Visitor interest was split evenly between lighting technology and building-services technology. 98% of them were satisfied with the range of products and services to be seen at the fair. The average time spent by visitors at the fair was two days. The poll of exhibitors produced an equally good result: 86% of them said they had achieved their goals for the fair. Manufacturers from all over the world emphasized the high level of visitor quality, in particular the decision-making authority and internationality of visitors, and the number of new contacts made in target groups of relevance to them.



Total Cost of Ownership (TCO, €) of various lighting strategies, including investment costs, operating costs, electricity consumption and change of light sources. They are compared on the base of the same illumination on the work plane (Units: Mlm.h = Mega.lumen.hours). Over the long term, daylighting is the cheapest technique to light spaces located near the building envelope, but it does not work at night. For the other spaces located deeper in the building, fluorescent lighting, and shortly combination of LEDs and Photovoltaic may be even cheaper.

Original source: Marc Fontoynont, Long term assessment of costs associated with lighting and daylighting techniques, Published in Light and Engineering, January 2008.

The next Light+Building will be held in Frankfurt am Main from 30 March to 4 April 2014.

REHVA organised a Seminar focusing on the Role of Lighting and HVAC in zero energy buildings during the exhibition. The participants appreciated the high quality presentations of REHVA experts.

Seminar programme

Nearly zero energy buildings and role of lighting
– Dr Jarek Kurnitski, Sitra, the Finnish Innovation Fund, Finland
Low energy lighting in cultural and heritage buildings
– Paul Ruffles FSLL, FCIBSE,UK
Lighting in low energy buildings or Retrofits of lighting installations
– Dr.-Ing. Jan de Boer
Group Leader Lighting Technology, Fraunhofer Institute of Building Physics, Germany
Integrated control of lighting, solar shading and HVAC for Nearly Zero Energy Buildings
– Anders Hall, SomFy, Sweden
Integration of lighting and air air-conditioning
– Mikko Lietzen, Halton , Manager, R&D, Finland

All presentations are available at the REHVA website www.rehva.eu.

An interesting summary of the cost of various light sources was included in the presentation of Dr.-Ing. Jan de Boer, Fraunhofer Institut for Building Physics, Stuttgart (see figure above). **OS, CD**

Participants of the REHVA General Assembly in Timisoara, Romania.

REHVA Awards 2012

On the occasion of the Annual Meeting 2012, the following members of REHVA national associations received a REHVA Award: **Prof. Dr. Eng. Adrian Retezan** and **Acad. Prof. Dr. Eng. Liviu Dumitrescu** (AIIR/AGFR – Romania) were recognized for their outstanding achievements in science and for their contributions to improve energy efficiency and the indoor environment of buildings.

Acad. Prof. Dr. Eng. ***Liviu Dumitrescu*** *(left) and REHVA President* ***Michael Schmidt****.*

Prof. Dr. Eng. ***Adrian Retezan*** *(left) and REHVA President* ***Michael Schmidt****.*

Dr. ***Laure Itard****. (on the right) and REHVA Secretary General* ***Jan Aufderheijde****.*

Dr. Laure Itard (TVVL – The Netherlands) received on the occasion of the General Assembly of TVVL a REHVA Professional Award as well.

Mr. ***Francesco Causone*** *and President of AiCARR Mr.* ***Michele Vio****.*

Francesco Causone (AiCARR – Italy) received a REHVA Young Scientist Award during the National Conference of AiCARR in Padua on June 7. **CD**

A REHVA Gold Medal Award, the highest REHVA recognition, was handed by REHVA President Michael Schmidt (right) to Prof. ***Olli Seppänen*** *(left) in recognition of his outstanding services to REHVA and for his excellent contributions to science and engineering in heating, ventilation and air-conditioning.*

Summary of the REHVA Annual Conference April 2012 in Timisoara

Olli Seppänen
Professor
oseppanen@rehva.eu

Important topics and the main conclusions of the conference

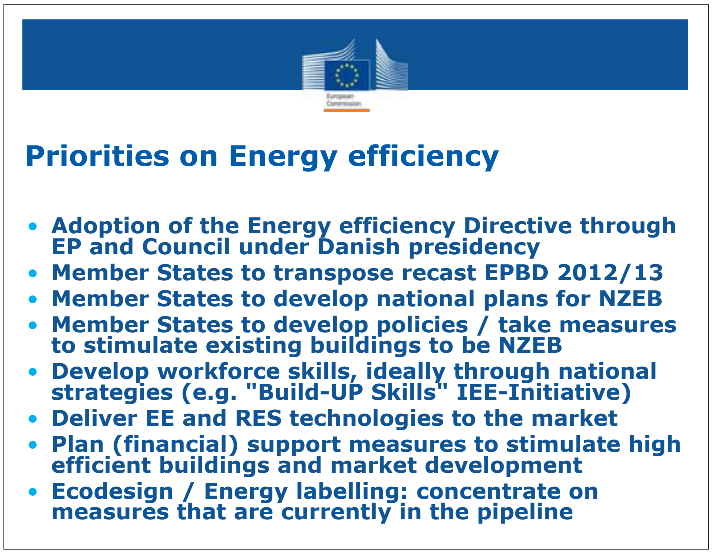
The main conclusion of the conference was that the low energy retrofitting of building is a huge challenge to the whole Europe, and the HVAC systems are a key contributor towards energy savings when the EU is to reach its target of reducing 20% the energy use by 2020.

The main topics of the conference were: how to improve the energy efficiency of the existing buildings, how to select the most cost effective methods to do it and how to motivate the building owners to implement the renovation of buildings.

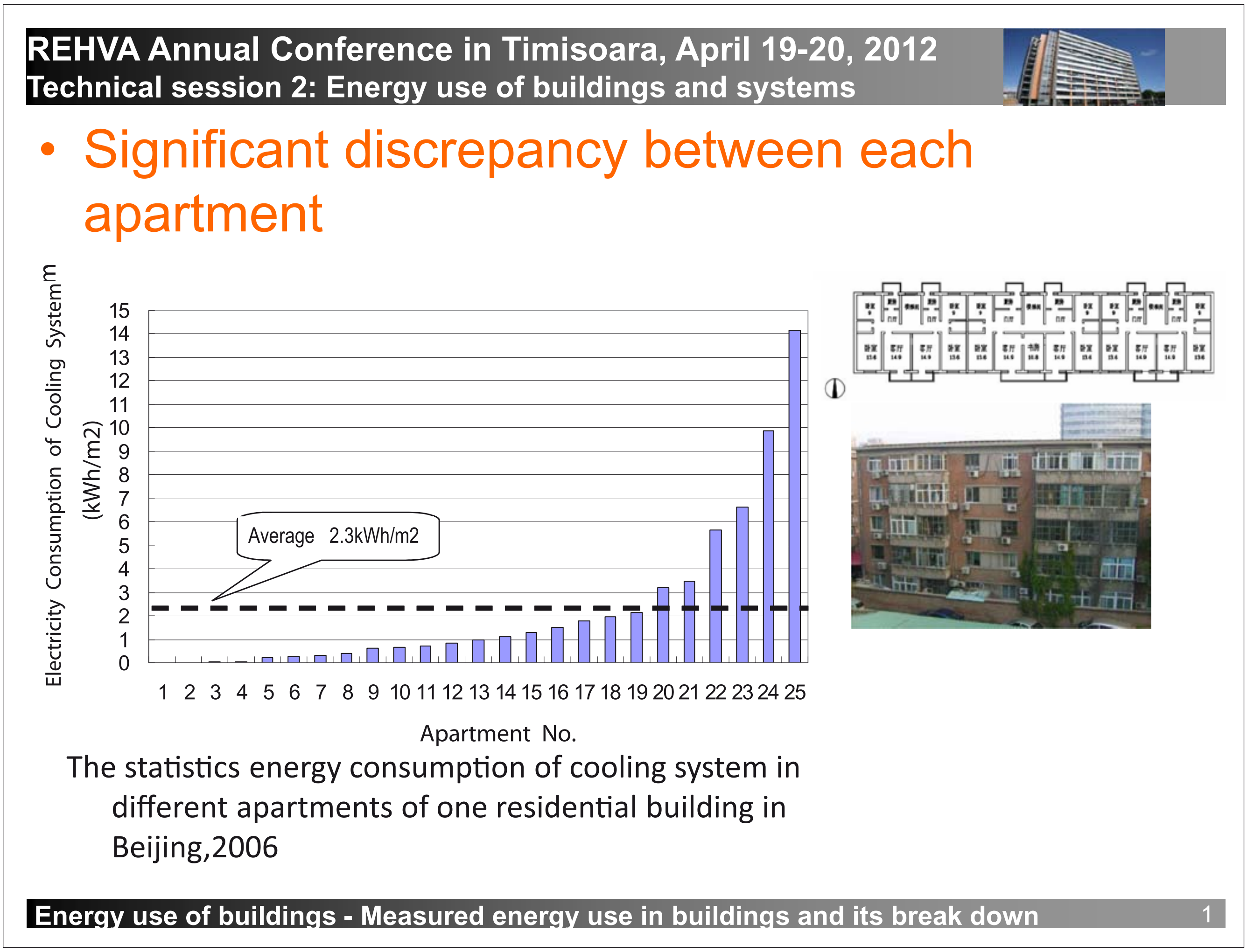
Several presentations were focusing on the recast Energy Performance of Buildings Directive (EPBD) which is the most important piece of legislation to help to achieve this goal of energy efficiency in the EU. Specifically, the introduction of "nearly zero-energy buildings" by 2021/2019 will create major changes in the building industry and construction practice during the next decade. All member states will have to develop minimum energy performance requirements to all buildings. Even there is no obligation to renovate the existing buildings the regulations for the new buildings will speed up also the refurbishment rate of the existing building stock.

The strengthening of Energy Performance Certificates and Inspections is required also in EPBD. This will require new legislation in many countries. The requirement for guidance of the energy improvement measures as a part of energy certificate requires qualified well trained inspectors. The training of the inspectors is a huge challenge for the engineering community.

International studies (like IEA Annex 53) showed how important the occupant behavior is when evaluating the total energy use in buildings. The energy use of similar apartments or houses may vary in the ratio 1:4 due to occupants´ behavior. This needs much more attention in the future. It was also evident that office appliances have become major component in the energy balance of office buildings.



Clemens Haury from the European Commission focused in his presentation on the main instruments of Energy efficiency policy and the priorities of future actions.



Professor **Hiroshi Yoshino** from Tohoku University, Japan, presented the summary of the IEA´s working group Annex 53 "Measured energy use in buildings and its break down" and pointed out how large variation in energy use can be due to the user. In the figure the variation electricity use of air conditioning in Chinese apartments.

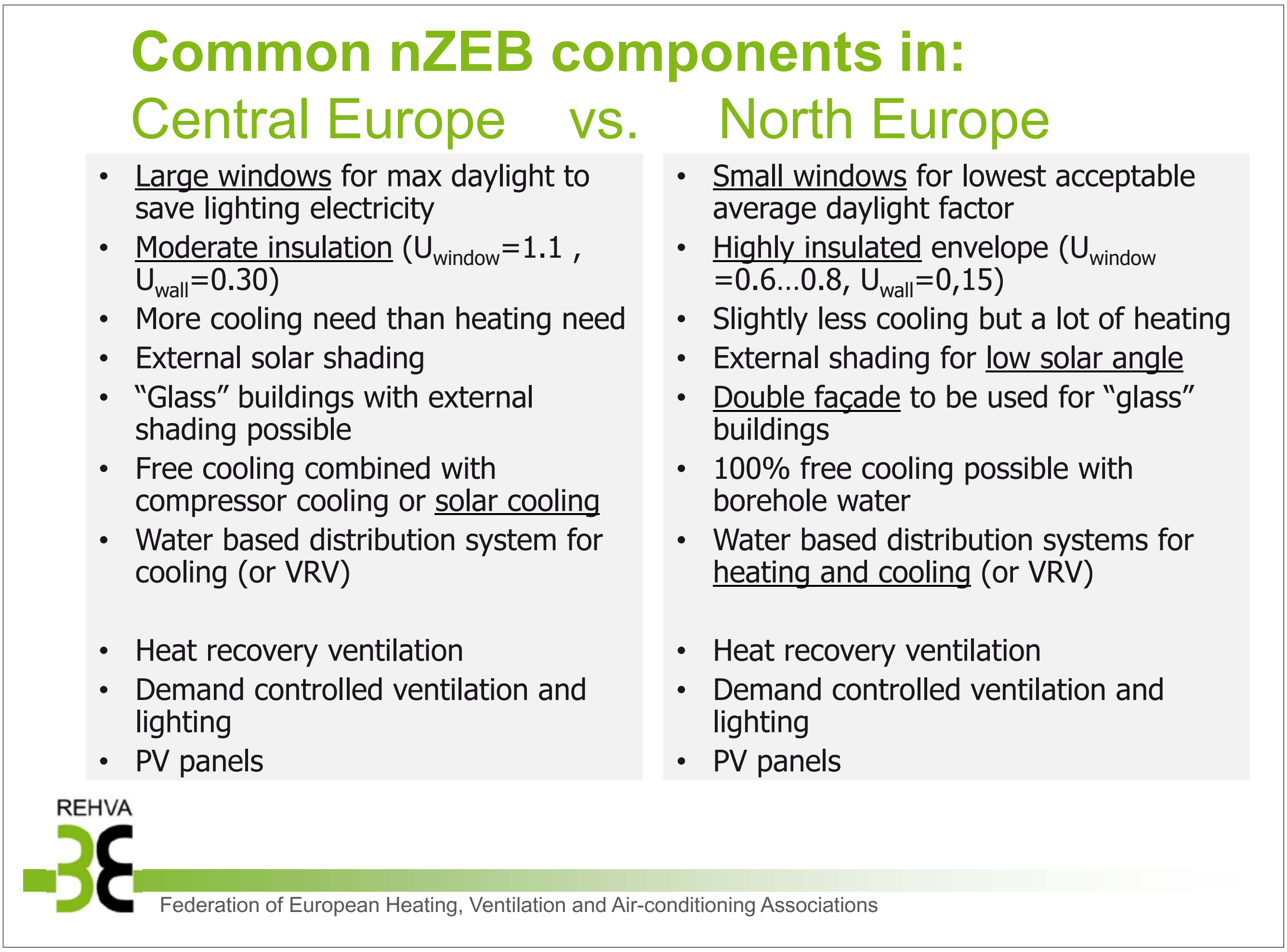
The European recast Energy Performance of Building Directive requires also the inspection of air-conditioning and heating systems. The presentation at the conference illustrated how the requirements in the directive can be implemented and how the good results can be achieved. Monitoring of the energy use of the building also revealed that the largest energy use in many office buildings is not due to HVAC but many other services in building like food and computer services.

Energy performance certificate (EPC) is required for all buildings. It is based on calculation of energy use with standardized operation schedules. However, buildings are never used exactly according to the predicted way.

The benefits of energy certificates based on measured energy use were widely discussed as they give also guidance to building owners regarding the need to take action for operational improvements. In UK, the measured energy use is used in the Display Energy Certificate (DEC) which is required parallel to EPC. DEC shows the actual energy use of the building compared to typical energy use of similar buildings of that type. It tells to building owner how effectively the building is managed. It is a measure of real operational energy use. It is based on energy use per unit area – quick and easy to measure and compared to an EPC. In the long run both calculated and measured certificates are needed.

The importance of HVAC technology in Energy retrofitting

Heating, ventilation and air condition systems play an important role when improving the energy performance of buildings. The studies have shown that in central system the balancing of the heating and improving the control system will bring significant saving in



Professor **Jarek Kurnitski** presented overview of net and nearly zero energy buildings and summary of the common technical features of nearly zero energy office buildings in northern and southern European conditions.

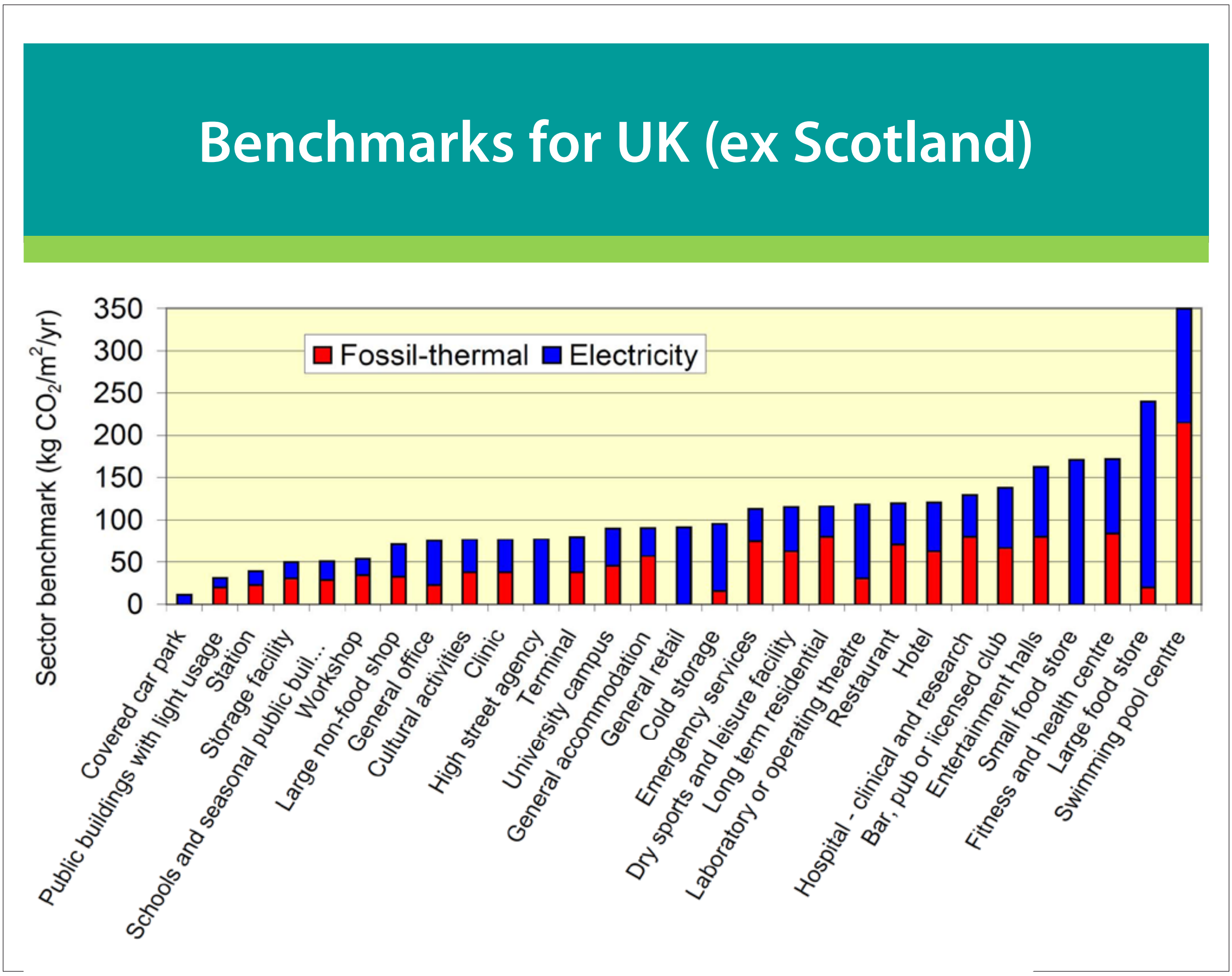
heating and at the same time improve the indoor environmental conditions. The following measures are particularly cost effective when improving the energy efficacy of heating system:

- Insulation of pipes of the heating and DHW distribution system
- Replacement of the heat generator with a more efficient one (i.e. with a condensing boiler or geothermal heat pump …)
- Introduction of technologies that employ renewable energy sources (solar system, biomass …)
- Connection of the heating system to district heating network (if available)
- High efficient distribution networks (pumps)
- Advanced control systems

Building and ductwork air leakage levels are reasonably well-known. It is also recognizes that a lot can be done to reduce to energy losses through building and duct leakage. Strict requirements for building and duct leakage should be imposed in all climates. Improvement of building air tightness is relative easy and cost effective, and professionals can rapidly integrate these issues in the construction practice. Testing is easy and can be rapidly integrated in a regulatory control schemes.

In the area of energy efficient ventilation the following measures were agreed to be very important in improving the energy efficiency:

> Control the ventilation and air-conditioning according to the use of the spaces and by installing demand controlled ventilation systems. In commercial buildings, in particular, ventilation rate should depend on level of occupancy. But also, in residential buildings operation of HVAC system should depend on the time of day (at home, outside), and room which are in actual use (living room, bedroom). Obvious need is for more representative sensors and better control concepts.



Donald Leeper from UK, emphasized in his presentation the importance of energy certificates based on measured energy use (Display Energy Certificate) widely used in UK. He also showed the benchmark values of CO2 emissions in different types of buildings developed by the REHVA British member CIBSE.

Commissioning of HVAC systems is important when reducing the energy use in buildings. The cost of commissioning is between 0,3 % and 0,7 % of the total development cost but the energy cost saving is between 5 % and 15 %. As the result of commission the system performs better and benefits can be seen such as: increased staff productivity lower maintenance costs and environmental protection.

Nearly zero energy buildings

The recast EPBD requires all new building to be nearly zero energy buildings by 2021. Such buildings have been already constructed. In general nearly zero energy building means:

Reduction of energy demand + **effective systems** + **on site renewables**

Common technical features in nearly zero energy office buildings were reported to be:

- Energy efficient energy sources and renewables to be used: heat pumps, DH, bio-CHP, solar PV and thermal
- Heat recovery ventilation; often demand controlled, by centralized or decentralized systems sometimes combined with natural stack effect ventilation for ventilative cooling purposes
- Free cooling solutions combined with mechanical cooling via boreholes, water to water HP, evaporative or ventilative cooling etc.
- Optimized building envelope and effective external solar protection
- Utilization of natural light + effective demand controlled lighting
- High efficiency heat recovery and low specific fan power;
- CO_2, presence and temperature control systems

- Water based distribution systems and VRV heat pumps
- Utilization of thermal mass and other passive measures

A common opinion of the conference participants was that in many cases the installation of heat pumps is a cost effective way to reduce primary energy use of buildings, particularly if the building has direct electrical heating.

REHVA activities for better buildings

REHVA – the Federation of European HVAC Associations has the improvement of energy efficiency of building in its agenda, and as an important part of its strategy. REHVA has several activities to help the members in implementing energy efficiency of buildings.

REHVA published two new guidebooks at its annual meeting, both helping building owner to make the building more energy efficient. These are:

- REHVA Guidebook 16: HVAC in Sustainable Office Buildings - A bridge between owners and engineers was created for building a bridge between the real estate community and the engineering community.
- REHVA Guidebook 17: The Design of energy efficient ventilation and air-conditioning systems.

REHVA has also several Task Forces developing new Guidebooks related to the energy efficiency of buildings such as:

- A REHVA Task Force on NZEB lead by Prof. Jarek Kurnitski continues its work for better definition on nearly zero energy buildings.
- A Task Force lead by Prof. Marija Todorovic is planning to publish three REHVA Guidebooks on the Energy retrofitting of the building in the near future.
- A new Task Force on "Environmentally friendly refrigeration system in buildings" lead by Attila Zoltan from Hungary in cooperation with UNEP
- Cold climate design guide in cooperation with ASHRAE lead from REHVA side by Prof. Bjarne Olesen.

On the EU level REHVA has supported the Commission when new regulations and directives are being developed. REHVA supports the ideas in the original Energy Efficiency Directive from the Commission with its target renovation rates, and binding requirements for the reduction of energy use and the leading role of the public sector. REHVA has also emphasized the fact that buildings are for people, and the first objective is to maintain in buildings good, healthy indoor environment, and that this target cannot be sacrificed when implementing energy efficiency improvements.

Changes during the REHVA 2012 General Assembly

REHVA General Assembly was held on Wednesday 18 April 2012 in Timisoara, Romania. The quorum voted for REHVA's next president and successor; **Prof. Karel Kabele** from STP, Czech Republic, was elected by the delegates for the position of President-elect.

Prof. Olli Seppänen announced that he will be stepping aside from the post of REHVA Secretary General. He will remain Editor-in-chief of the REHVA European HVAC Journal and active member in several REHVA committees. The new Secretary General, **Jan Aufderheijde**, who was previously a REHVA Vice-President and the managing director of the Dutch Association TVVL, was introduced to all the National Associations members.

*Professor **Olli Seppänen**, REHVA President **Michael Schmidt** and the the new Secretary General **Jan Aufderheijde.***

Mr. Jarek Kurnitski, reserve member of the board from EKVU, Estonia, will replace **Mr. Aufderheijde** as a board member. **CD**

REHVA International student Competition 2012 in Timisoara, Romania

The 2012 REHVA International Student competition was held in Timisoara, Romania during the REHVA Annual Conference in April 19-20.

The call of REHVA's Education Committee under the chair of **Prof. Dr. ing. Karel Kabele** to participate in the international student competition of REHVA brought 8 entries this year. Eight national champions participated in this competition. "The presentations and of the posters were all very good concluded **Prof. Karel Kabele**, chair of the Education committee after the presentations. The judges were quite impressed with all the students". None of the candidates is a native speaker so there was an equal playing field for all of them concerning that aspect of the presentation (oral and poster). The winner of this year's edition is **Rik Maaijen** from the Technical university of Eindhoven in The Nederlands for his work on "Occupant-oriented energy control by taking the human in the control loop of building systems". The work was supervised by **Prof. Wim Zeiler**.

The work of the winner is introduced to the readers in a short summary on page 34 and full lenght paper at www.rehva.eu. **CD**

Another Fruitful Danvak Conference

By **Zosia K. Lav**, Communications Manager at Danvak

According to tradition Danvak – the Danish Society of Heating, Ventilation and Air Conditioning – held its annual conference on HVAC issues in April. The Conference, called Danvak Dagen (The Danvak Day) was attended by 145 people and the exhibitors represented included KNX National Group Denmark, WindowMaster, TT-Coil, Swegon and Dansk Ventilation.

The annual conference Danvak Dagen was attended by 145 people.

The aim of the annual conference is to provide a forum for academics, professionals, engineers, architects and journalists from the HVAC field to meet and exchange their ideas, results and latest research. To ensure the balance between delegates from the academic world and from industry, delegates from the latter are invited to describe their practical experiences and set new challenges for the development of product design.

Once again the recipient of the prestigious Professor P.O. Fanger's Award was announced at the conference. Unfortunately, the recipient of the award, ph.d. student Michal Spilak, was unable to receive the award in person as he was attending a Conference in Texas. He did, however, manage to thank the Award Committee and to join the conference delegates in Denmark by showing a video that he had recorded and uploaded to Youtube. Michal Spilak was nominated by SBI, Aalborg Universitet (Danish Research Institute, Aalborg University) for his research on 'Intervention studies in Danish Dwellings'. The aim of his Ph.D. project is to obtain a wider knowledge on scientific methodology in relation to intervention studies in dwellings and, in particular, in relation to the reduction of concentrations of particles and allergens.

Professor Bjarne W. Olesen has been awarded Order of Dannebrog

Wednesday June 20th, Prof Bjarne W. Olesen has received the Order of the Dannebrog (name of the Danish national flag) from the Danish Queen.

The Order of the Dannebrog (Danish: *Dannebrogordenen*) is a Knight Order of Denmark, instituted in 1671 by king Christian V. Today, the Chivalric Order of Dannebrog is a means of honouring and rewarding the faithful servants of the modern Danish state for meritorious civil or military service, for a particular contribution to the arts, sciences or business life for those working for Danish interests.

Bjarne W. is a full professor in Indoor Environment & Energy at the Technical University of Denmark and director of the International Centre for Indoor Environment and Energy. He is also a Vice-president of REHVA and a member of the Board of Directors.

Air pollution from diesel engines exhausts causes cancer – *What consequences for Indoor Air Quality?*

On 12 June 2012, the International Agency for Research on Cancer (IARC), of the World Health Organization (WHO), classified diesel engine exhausts as carcinogenic to humans, based on scientific evidence, reviewed thoroughly by a Working Group of experts, that exposure is associated with an increased risk for lung cancer. Indeed, diesel engine exhausts emit ultrafine particulate matters (PM2.5) that are damaging for human health. Ultrafine particulate matters are not only found outdoors, but also in households due to the infiltration of these pollutants into buildings.

The classification change by IARC confirms the urgent need to reduce air pollutant emissions from diesel engines, and better integrate indoor air quality in all relevant policies in the field of energy efficiency, public health and air quality strategy, particularly in light of the review of the EU air quality strategy in 2013.

A report issued in the framework of the Clean Air For Europe (CAFE) programme revealed that more than 300,000 people die prematurely from health impact of air pollution every year in the EU27. In 2009, the EnVIE (Co-ordination action on IAQ & Health Effects) report published by DG Health and Consumers already linked Indoor air pollution to cardiovascular and respiratory diseases. It also recognized the specific impact of ultrafine combustion particles PM2.5. According to the same report, EU citizens spend 90% of their lives indoors, where outdoor air pollution infiltrates.

Regarding the best available technologies and policies instruments, the combination of source emission reduction in building materials on one hand, with minimum requirements regarding ventilation rates associated to efficient air filtration should be part of the strategy, and precautionary measures to reduce people exposure to air pollution that infiltrates from outdoor inside our buildings.

Air filtration is at the forefront of clean technologies, delivering energy efficient solution to help creating healthy indoor environments. In light of 2013 – year of the air, indoor air quality should be a key element of the debate. Despite of high potential benefits for health, indoor air quality is often overlooked by policymakers. We recommend the development of a framework strategy on indoor air quality in order to assess opportunities for further policy action. We suggest in parallel that minimum requirements for ventilation and filtration are integrated into relevant EU policies.

Myriam Tryjefaczka, CAMFIL FARR Group,
Sustainability Officer, myriam.tryjefaczka@camfil.fr

New Swegon Air Academy website

www.swegonairacademy.com

air academy Swegon

Serious and up-to-date information on HVAC developments just got more easily accessible!

Swegon Air Academy contributes to increased awareness about subjects such as energy issues, healthy indoor environments, ventilation knowledge and environmental challenges. The aim is to provide overviews of current issues in an objective and impartial manner by engaging highly distinguished experts from a representative cross-section of the industry's different sectors.

Swegon Air Academy offers a free membership for everyone and anyone who has an interest in indoor climate and its symbiotic relationship to building energy use. By a quick and simple on-line registration you can join a network which connects you to experts on a professional level. The new website also provides access to interesting information about our seminars, lecturers, presentations, publications, as well as many other benefits.

For more information visit http://www.swegonairacademy.com/ today and keep up-to-date with the latest developments in innovative indoor climate and air handling!

VDI- Guidelines published April - July 2012

D VDI 3810/4 “Operating and maintenance of building services; Ventilating and air-conditioning installations”
The guideline applies to the operation and maintenance of VAC installations and VAC equipment (centralized as well as decentralized).

D VDI 3819/2 “Fire protection in Building Services; Functions and correlations”
The technical systems for detection of fire and the technical solutions to save life or property have influence on each other in their effect. The guideline describes the typical operational systems running on the brand and interactions with other systems.

VDI 6007/3 “Calculation of transient thermal response of rooms and buildings; Modeling of solar radiation “
The computation techniques specified in this guideline serve as modules for computations of the in stationary thermal response of rooms and buildings; they are, therefore, part of the room model as per VDI 6007 Part 1.

D VDI/DVGW 6023 “Hygiene in drinking-water installations; Requirements for planning, execution, operation and maintenance”
The guideline applies to all drinking-water installations on premises and in buildings. It contains guidance for planning, erecting, commissioning, use, operation and maintenance of any drinking-water installation. The significance of drinking-water installations for healthy living and working requires the involvement of, and agreement between, all parties involved in the planning, erection, operation and maintenance.

D VDI 2067/30 “Economic efficiency of building installations; Energy effort for distribution”
This guideline specifies the calculation of the energy effort for the distribution of heating energy between a central heat generator or chiller and distributed points of use.

VDI 2073/2 “Hydraulic systems in building services; Hydraulic balancing”
This guideline applies to the dimensioning of new, and verification, by calculation, of existing, distribution systems for heating and chilling in HVAC installations; its particular aim is the reproducible hydraulic balancing of an installation as planned.

VDI 3810/1 “Operation and maintenance of building installations; Fundamentals“
The series of guidelines VDI 3810 gives recommendations for the various building services and trades regarding safe, specified, demand-oriented and sustainable operation.

VDI 3814/7 “Building automation and control systems (BACS); Design of user interfaces”
The guideline is intended to create a unified basis serving to simplify the planning, execution and acceptance of management and operating equipment.

D = Draft Guideline

VDI 3819/1 “Fire protection in building services; Acts, ordinances, technical rules”
The guideline provides an overview of laws, regulations and technical rules to be followed in connection with the fire protection in the various provinces and in the various trades of building services.

D VDI 6002/1 “Solar heating for potable water; General principles; System technology and application in residential buildings”
This guideline deals with solar-powered potable-water heating.

D VDI 6022/6 “Ventilation and indoor-air quality; Air humidification on decentralized devices; Planning, construction, operation, maintenance”
This guideline applies to the intended and local humidification of air by means of standalone units as well as for decorative water-carrying devices (such as fountains, cascades and water walls) which affect the air humidity in a room.

VDI 2083/3.1 “Cleanroom technology; Metrology in cleanroom air; Monitoring”
This guideline deals with the permanent installation-specific monitoring of individual parameters of controlled environments.

D VDI 3807/5 “Characteristic energy-consumption of buildings; Partial characteristics for thermal energy”
This guideline specifies the determination and use of partial characteristics for thermal-energy consumption, either calculated or derived from measured values.

D VDI 6028/1.1 “Assessment criteria for Building Services; Technical quality for sustainable buildings”
In this guideline, evaluation criteria for the sustainability of building services are provided. The criteria are applicable to all trades of building services.

D VDI/GVSS 6202/1 “Decontamination of contaminated buildings and installations”
The guideline applies to activities of demolition, refurbishing, maintenance and servicing of building structures and building services, where contaminants are involved. It applies to the removal, coating and separation of contaminants and the consignment and handover of the waste generated to disposal

VDI 4708/1 “Pressure maintenance, venting, deaeration; Pressure maintenance”
This guideline applies to the media circulation in heating systems where the interruption of operation or of forced circulation is a regular occurrence (e.g. interruption of heating in summer) during operation.

VDI 6036 “Fasteners of radiators; Requirements for planning and design”
The aim of this guideline is to give companies and individuals who are engaged in the design and construction of heating systems, in compliance with the Product Safety Act (ProdSG), guidance in the selection and design of radiator fixings.

SCANVAC NEWSLETTER

SCANVAC - SCANDINAVIAN FEDERATION OF HEATING, VENTILATION AND SANITARY ENGINEERING ASSOCIATIONS IN DENMARK, FINLAND, ICELAND, NORWAY AND SWEDEN

"Scanvac Newsletter 1/2012 - Online at www.scanvac.net!"

- Coming events
- Doctoral Theses
- Awards

- Articles

• New boost on consumer energy advice in Finland

• Great potential for energy efficiency in Norway

• SEPEMO seminar on field measurements of heat pumps in Stockholm

• Fruitful Danvak Conference

• Ground Source Heat Pump sales increased 72% in Finland

...and more

Trailblazing Belimo Energy Valve™:

Know where the energy is going

With its unique *Energy Valve*, Belimo is presenting a trailblazing novelty: Innovative valve technology in combination with the most up-to-date IT makes it possible to monitor the energy consumption of heating and cooling circuits in an uncomplicated manner and to correct them at any time.

The *Energy Valve* is the next logical development of the electronically controlled, pressure-independent characterised control valve (CCV) EPIV. Just like its predecessor, it can measure, control, balance and shut. As a result, not only the valve configuration is considerably easier: because the flow rate is electronically measured and balanced on a permanent basis, consumption is optimised and the time required for hydraulic balancing is markedly reduced. The characterising disk, which has already proven itself millions of times over, ensures an equal percentage valve characteristic curve, and the ball-shaped soft seal prevents circulation losses in the water circuit.

But that's not all. With the *Energy Valve* – besides the flow rate sensor – two additional sensors also measure the medium temperatures in the supply and return. That means that energy consumption is determined on a continuous basis and saved on the web server integrated in the actuator for 13 months. Using a laptop (RJ45 Ethernet interface) or by means of the management system, the values can be viewed, analysed and – if necessary – optimised onsite directly through the valve.

The Belimo Energy Valve™ can measure, control, balance and shut. And it is the first valve to also show where the energy is going.

More information: www.belimo.eu

New efficient filter from Camfil *for air handling units*

Camfil has developed a low pressure drop filter that removes the particulate matter effectively but also gaseous pollutants including ozone from ventilation air.

Advantages

Its pressure drop is exceptionally low and it meets the Eurovent Certification energy class A. City-Flo XL has the same plastic frame (a single-piece casting) used in many of Camfil other filters. When upgrading the existing filters, there is no need to replace the filter system. City-Flo XL has been developed to achieve a better indoor environment that satisfies EN13779:2007, the European standard for indoor air quality.

Innovation

Camfil new air filter, City-Flo XL, is a combination filter that removes both particles and gases from ventilation air. Filter contains activated carbon, it also removes odours and aromas that ordinary air filters miss. Unique filter media has classF7 particle removal. For gas cleaning, activated carbon is integrated in the non-woven filter media. City-Flo XL filter removes also ozone from the ventilation air.

Technical data:

Filter type: Particle and gas filter.

Frame: Plastic XTL frame, single piece casting, good air distribution in the filter.

Filter media: Fiberglass particle filter layer (fine fibres) with very high quality coconut shell carbon integrated into non-woven media.

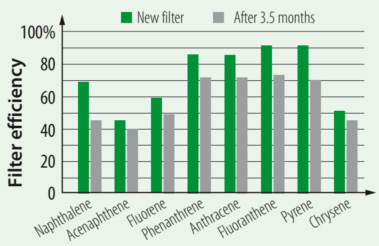
Filter class: F7 (as pr EN779:2012).

Filter design: Stiff bags – carbon composite media downstream. Atmospheric humidity in test conditions 70%.

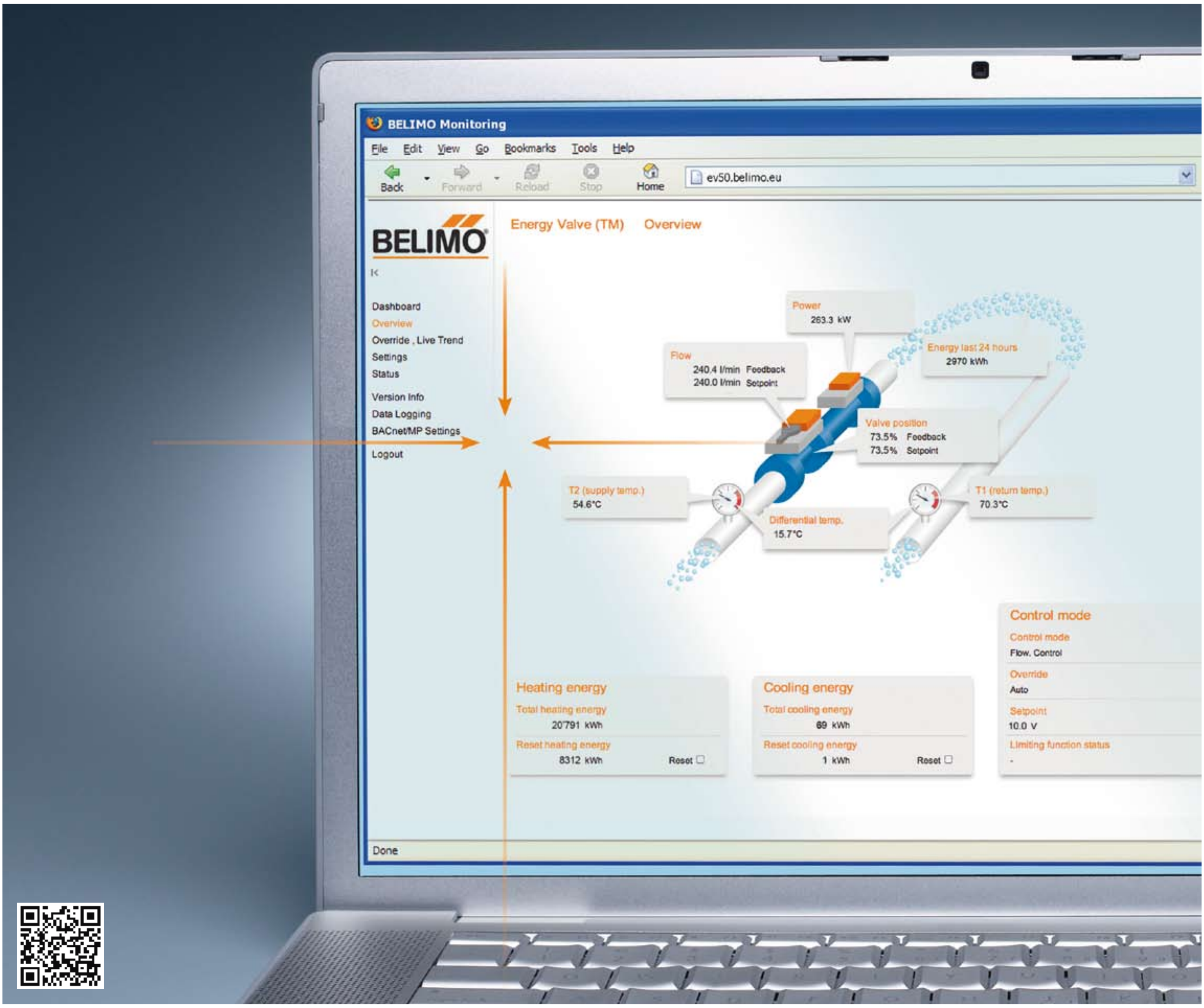
Performance:

- Filter class F7 regarding the particle removal efficiency according to European standard EN 779:2002.
- Pressure drop and removal efficiency of some gaseous pollutants below.
- Significant improvement of perceived quality of air passing through the filter.
- City-Flo XL is also Eurovent certified and P marked by Swedish Testing Institute.

More information: www.camfilfarr.com



CITY-FLO XL combination filter.



We make energy currents visible. You optimise the water circuits.

EXPERIENCE
EFFICIENCY

In addition to the flow rate, the sensors in our electronically regulated Energy Valve™ also measure the temperatures in the supply and return lines, e.g. with heat exchangers. The values are saved in the integrated webserver for up to 13 months and are visible, e.g. onsite on the laptop. The current consumption can also be depicted on the management system. This way, you can analyse and document which direction the energy is flowing to and optimise the energy flows of the hot and cold water circuits at any time.

BELIMO Automation AG, Brunnenbachstrasse 1, CH-8340 Hinwil
Tel. +41 43 843 61 11, Fax +41 43 843 62 68, info@belimo.ch, www.belimo.com

BELIMO®

Events & Fairs 2012 - 2013

EVENTS 2012

10 – 11 Oct	**33rd AIVC Conference and 2nd TightVent Conference**	Copenhagen, Denmark	www.tightvent.eu
10 – 11 Oct	**Building Services - The CIBSE Conference & Exhibition**	London, United Kingdom	www.buildingservicesevent.com
11 Oct	**Renovate Europe Day**	Brussels, Belgium	www.renovate-europe.eu
17 – 19 Oct	**47th Conference of plants – "Plants for the early third millenium"**	Sinaia, Romania	www.aiiro.ro
19 Oct	**30th National Conference in Bologna**	Bologna, Italy	www.aicaar.org
23 – 26 Oct	**12th International Conference for Enhance Building Operations**	Manchester, England	www.icebo2012.com
12 – 14 Nov	**7th International HVAC Cold Climate Conference**	Calgary, Alberta, Canada	http://ashraem.confex.com/ashraem/icc12/cfp.cgi
21 – 23 Nov	**EME3 1st World Meeting on Energy Efficiency in Buildings**	Madrid, Spain	www.encuentroEME3.com
5 – 7 Dec	**43th International congress of Heating, Air Conditioning and Refrigeration**	Belgrade, Serbia	www.kgh-kongres.org/

FAIRS 2012

9 – 11 Oct	**Chillventa 2012**	Nuremberg, Germany	www.chillventa.de/en/
9 – 12 Oct	**Finnbuild 2012**	Helsinki, Finland	www.finnbuild.fi
17 – 18 Oct	**CEP® Clean Energy & Passive House Expo**	Budapest, Hungary	www.cep-expo.hu

EVENTS 2013

26 – 30 Jan	**ASHRAE 2013 Winter Conference**	Dallas, Texas, USA	www.ashrae.org/membership--conferences/conferences/dallas-conference
15 – 17 Apr	**3rd International Conference in Microgeneration and Related Technologies in Buildings - Microgen III**	Naples, Italy	www.microgen3.eu
9 – 11 May	**5th International Conference on Amonia Refrigeration Technology**	Ohrid, Macedonia	www.mf.edu.mk
27 – 28 May	**36th Euroheat and Power Congress**	Vienna Austria	www.ehpcongress.org
June	**Climamed 2013**	Istanbul, Turkey	www.climamed2013.org
7 – 8 June	**The Latest Technology in Air Conditioning and Refrigeration Industry**	Milan, Italy	www.centrogalileo.it/milano/CONGRESSODIMILANO2013english.html
16 – 19 Jun	**11th REHVA world congress Clima 2013**	Prague, Czech Republic	www.clima2013.org
22 – 26 Jun	**2013 ASHRAE Annual Conference**	Denver, Colorado	www.ashrae.org/membership--conferences/conferences/ashrae-conferences/denver-2013
26 – 28 Jun	**Central Europe towards Sustainable Building Prague 2013**	Prague, Czech Republic	www.cesb.cz/en
25 – 27 Sep	**5th International Conference Solar Air-Conditioning**	Kurhaus Bad Krotzingen, Germany	www.otti.eu
15 – 18 Oct	**IAQ 2013 - Environmental Health in Low Energy Buildings**	Vancouver, British Columbia, Canada	www.ashrae.org/membership--conferences/conferences/ashrae-conferences/iaq-2013

FAIRS 2013

28 – 30 Jan	**AHR Expo**	Dallas, Texas, USA	www.ahrexpo.com
5 – 8 Feb	**Aqua-Therm Russia 2013**	Moscow, Russia	www.aquatherm-moscow.ru/en/home/
27 Feb – 1 Mar	**World Sustainable Energy Days - the WSED 2013**	Wels, Austria	www.wsed.at
7 – 9 Mar	**ACREX 2013**	Mumbai, India	www.ishrae.in
12 – 16 Mar	**ISH Frankfurt**	Frankfurt, Germany	www.ish.messefrankfurt.com

REHVA
Federation of European Heating, Ventilation and Air-conditioning Associations
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REHVA SUPPORTERS

A REHVA supporter is a company or an organisation that shares the same objectives as REHVA. Our REHVA supporters use the latest European technologies to make their products. The REHVA Supporters are also members of reHVAClub. For more information about REHVA supporters' program, please contact info@rehva.eu or call +32 2 5141171.

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BELIMO · Caisse des Dépôts · camfil FARR · CIAT · CLIMESPACE GDF SUEZ · DAIKIN

Demark Construct confortul de partea ta · EMERSON Network Power · Enventus Energy Recovery · EPEE European Partnership for Energy and the Environment · ES-SO European Solar-Shading Organization Energy Savings & Comfort

EUROVENT CERTIFICATION · evapco · Flanders Foremost in Air Filtration · FläktWoods · FRITERM Termik Cihazlar Sanayi ve Ticaret A.Ş.

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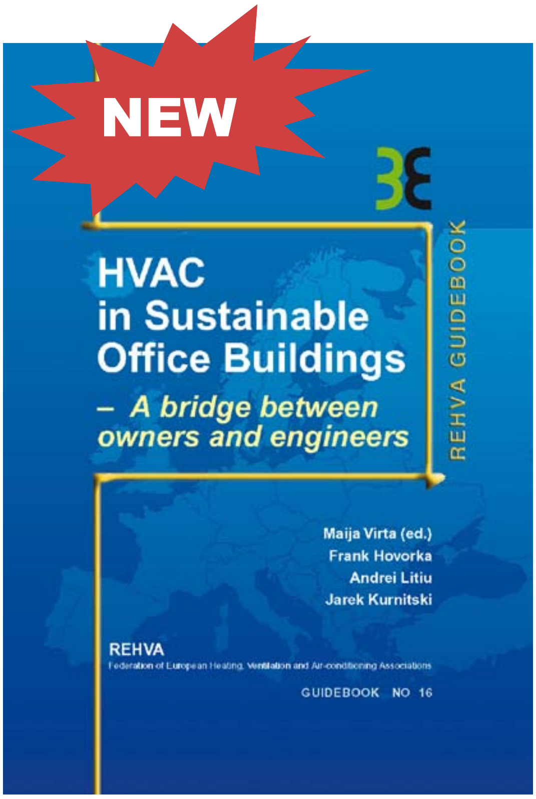
New REHVA Guidebooks

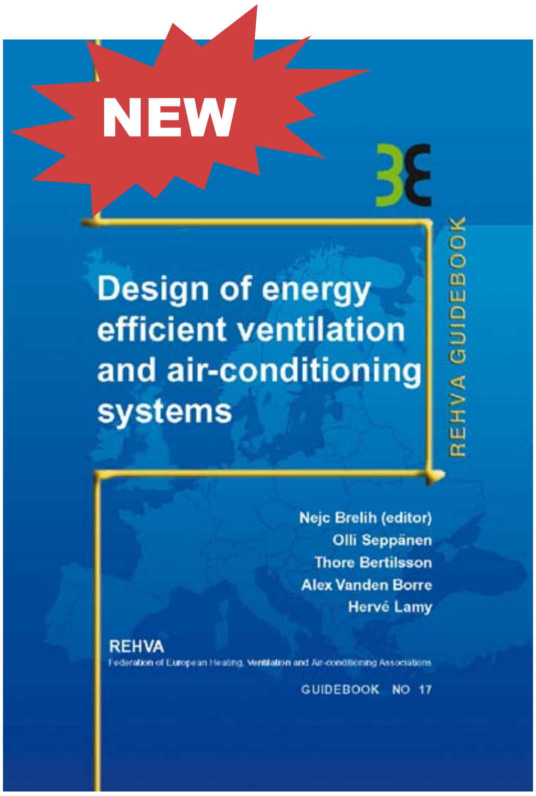


HVAC in Sustainable Office Buildings
– A bridge between owners and engineers

Editor: Maija Virta

Contributing Authors: Frank Hovorka, Andrei Litiu and Jarek Kurnitski

This book was created for building a bridge between the real estate community and the engineering community. It explains the challenges of property valuation based on real data and how the sustainability and HVAC-technology can have an impact on value. HVAC in Sustainable Office Buildings gathers the latest HVAC- and other technologies used in sustainable buildings and gives some real case study examples. Maybe the most important part in terms of improved communication between the owners and engineers is the list of questions to be asked during the life time of a building. It is impossible to give the right answers in this book, but we can raise some pertinent questions. As climates and cultures are different, as well as existing building types and energy production, the same solutions do not solve problems universally.



Design of energy efficient ventilation and air-conditioning systems

Editor: Nejc Brelih

Contributing Authors: Olli Seppänen, Thore Bertilsson, Alex Vanden Borre and Hervé Lamy

This guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high quality products once they are installed in the building system.

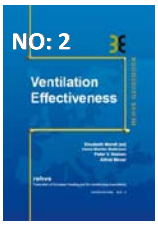
REHVA

REHVA Guidebooks are available at www.rehva.eu or through REHVA National Members

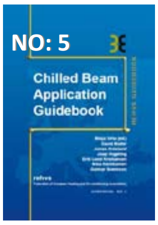
Federation of European Heating, Ventilation and Air-conditioning Associations

REHVA GUIDEBOOKS

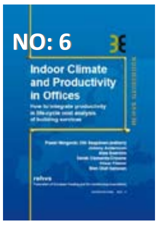
REHVA Guidebooks are written by teams of European experts



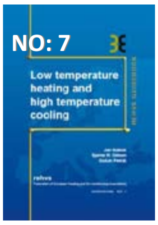
Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand descriptions of the indices used to mesure the performance of a ventilation system and which indices to use in different cases.



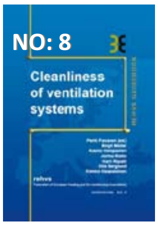
Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system. Primary air supply induces room air to be recirculated through the heat exchanger of the chilled beam. In order to cool or heat the room either cold or warm water is cycled through the heat exchanger.



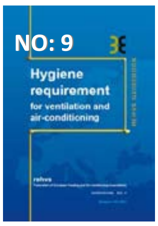
Indoor Climate and Productivity in Offices Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The quantitative relationships presented in this Guidebook can be used to calculate the costs and benefits of running and operating the building.



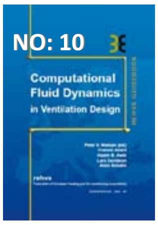
This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at low temperatures for heating and relatively high temperature for cooling.



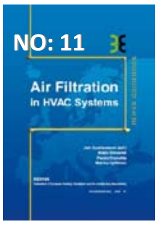
Cleanliness of ventilation systems Guidebook aims to show that indoor environmental conditions substantially influence health and productivity. This Guidebook presents criteria and methods on how to design, install and maintain clean air handling systems for better indoor air quality.



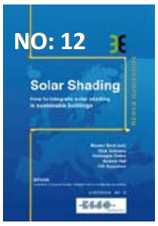
Hygiene requirement is intended to provide a holistic formulation of hygiene-related constructional, technical and organisational requirements to be observed in the planning, manufacture, execution, operation and maintenance of ventilating and air-conditioning systems. These requirements for ventilating and air-conditioning systems primarily serve to protect human health.



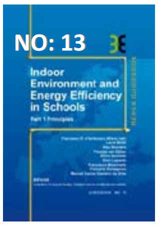
CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) – in Ventilation Design models is written by a working group of highly qualified international experts representing research, consulting and design.



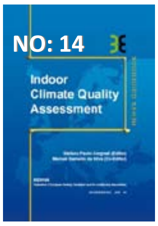
Air filtration Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such as levels of existing pollutants, indoor air quality and energy efficiency requirements.



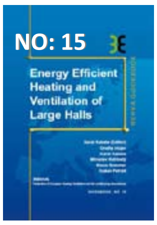
Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for selection, installation and operation of solar shading as well as future trends in integration of HVAC-systems with solar control.



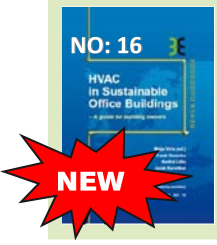
School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly on energy efficient systems for a healthy indoor environment.



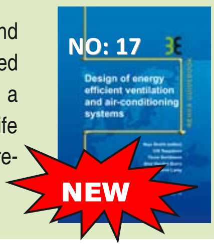
This new REHVA Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring has allowed enlarging significantly number of possible applications, especially in existing buildings. The Guidebook illustrates with several cases the instrumentation for the monitoring and assessment of indoor climate.



This guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various heating systems are illustrated with case studies. Design principles, methods and modeling tools are presented for various systems.



This guidebook talks about the interaction of sustainability and Heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.



This guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high quality products once they are installed in the building system.

www.rehva.eu ● info@rehva.eu ● REHVA Office: 40 rue Washington, 1050 Brussels—Belgium ● Tel + 32 2 514 11 71 ● Fax +32 2 512 9062

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